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AND ABSTRACT OF THE LITERATURE

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Reducing the Cost of Syphilis in Industry (Report of 176 Cases)

A Clinical and Laboratory Investigation of the Effect of Metallic Zinc, of Zinc Oxide, and of Zinc Sulphide upon the Health of Workmen

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THE JOURNAL OF INDUSTRIAL HYGIENE

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REDUCING THE COST OF SYPHILIS IN INDUSTRY (REPORT OF 176 CASES)*

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AND

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SIR William Osler has said that if physicians know syphilis in all its manifestations, all things clinical will be added to them. This inspiring invitation from such a great master should act as a challenge to all physicians working in industry. Industry offers a rich field for the study of syphilis, for it is here that an opportunity is given to study the individual from day to day and from year to year in relation to his daily work. Viewed from the public health point of view there need be no arguments advanced in favor of this type of endeavor. The reasons are altogether too obvious. In the 176 cases, a résumé of which is herewith presented, syphilis is represented in a great many of its manifestations from the primary to the tertiary lesion.

During the last three years we have taken bloods for Wassermann reactions, as follows:

1923	932
1924	1,237
1925	1,278
	3,447

Between 3.5 and 4 per cent. of bloods taken were positive. Usually bloods which were at first reported as faintly suspicious to cholesterin later became positive.

In the course of taking the blood for this number of Wassermanns, a technic was evolved which seemed to have certain merits. The nurse was placed in front of the extended arm so that the patient did not see the withdrawn blood. If the patient

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has any objection to the removal of blood it is not done. As a matter of fact such objections are almost never encountered. The Wassermann reaction is obtained in every accident no matter how trivial, and as many as seem practicable are taken in disease conditions. While the number taken in one day is frequently not large, when carried on year after year the total number comes to represent a survey of almost 60 per cent. of the older employees.

Even though the total number of blood specimens taken is relatively large, we have had no mishaps and there have been practically no complaints directed at this type of service.

Dr. W. C. Menninger[1] has shown that in 72 per cent. of his syphilitics there was difficulty in wound healing following operation. Practically all standard books of surgery recognize that syphilis is an additional hazard in operations.

The following cases illustrate the practicability of discovering syphilis and the application of the procedure to industry. While it will be noted that many employees claim that their disease came because of some condition connected with the work, there is not an instance where an employee claimed that he contracted the disease from another employee. In other words, in the 176 cases there is no claim on the part of any employee that he was infected by another.

A female employee struck the back of her hand against a machine; the injury did not yield to ordinary treatment, the pain continued for over one month, and the patient was dissatisfied. Another employee was struck with the handle of a truck in the left groin, which broke down, discharging pus, and there was general enlargement of other nodes besides those struck; the case dragged along for some time without a cure. Another employee fell, striking his knee; six months later he developed soreness, tenderness, and some swelling in the knee, conditions which he traced to the preceding fall, claiming compensation. A woman claimed that a furuncle in the groin was the result of a fall. Three employees complained of back injuries with prolonged residual pain. Nine employees had infections of the fingers, five of which were almost impossible to heal. Four workers claimed that their skin was being poisoned by conditions of their work; each had a macular eruption on the forehead and felt that it came from chemicals. There were four others who had leg ulcers, claiming injury by striking against objects. One employee believed that chemicals were causing him to lose his vision in one eye; in two months his vision had dropped from 20/20 to 20/200 in one eye.

In every one of these twenty-five cases, the Wassermann was 4 plus, and antisyphilitic treatment cleared up the condition. The compensation aspect of the case was forgotten when a cure was effected. What the saving was financially is difficult to say, but we know that it must have been great when we consider that the award for one eye is $4,000. Certainly the protection which has been effected in every case more than compensates for the cost of this service.

[1]Menninger, W. C.: Wound Healing in Syphilis. Am. Jour. Syphilis, 1925, *9*, 445.

With this in mind, it would seem that the best way to avoid complications of injuries is to anticipate them.

To those industries which pay sick benefits as well as accident compensation, this work becomes of added interest. Ordinarily there is more money paid out in sick benefits than in accident compensation. It is here that our diagnosis is of assistance to the patient in securing proper treatment, and the Company is saved a great deal in sick benefit.

For example, one employee asked for a three months' sick leave, planning to change climate. This ordinarily would have been given with pay. The Wassermann reaction was found to be 4 plus. After receiving treatment at a public clinic the improvement was so marked that a sick leave was no longer thought necessary.

One employee lost 517 hours during the first six months of 1924. After treatment, in the last six months of the year he lost 192 hours; and in 1925 he lost 50 hours. Another employee lost 203 hours in 1922 and 203 hours in 1923; after treatment, in 1924 he lost 12 hours; and in 1925 he lost 30 hours. Without treatment the tendency, of course, would be to lose more and more time every year. The saving in sick benefits is obvious.

Many other illustrations could be given of employees who were absent because of this disease. The list is so long that only classical examples may be cited. The value from the patients' point of view cannot, of course, be estimated in terms of dollars and cents. Such benefits must necessarily greatly exceed any financial considerations which may enter into a discussion of this series of cases.

The 176 cases reported here were discovered as follows: forty-nine employees who had lost time because of sickness had a Wassermann reaction taken on their return to work. This had not been done by the family physician. In every case it was positive. This fact shows the value of the examination after a period of sickness; it also shows how much may be overlooked by failure to take the Wassermann. Twenty-eight cases were discovered on preliminary physical examination. Of these, six never reported for work. Here is an illustration of the value of physical examinations. Thirty cases were discovered after accidents and sixty-nine as a result of other conditions.

Clinically, we had one primary lesion of the lip proved by the Wassermann and dark field examination. We had three cases of secondary lesion, and the remainder were of the latent or tertiary state. One patient had gross swelling of the lymphatic cervical chain resembling a sarcoma. It promptly melted away under antisyphilitic treatment. Two patients had tertiary gummas of the nose. One of these had a curious complex—he persisted in sounding the fire alarm, as the resulting confusion stimulated his unbalanced imagination. He was also very forgetful. He returned to normal following treatment and has continued to work since.

From an industrial point of view there is no symptom which is more difficult to handle than syphilitic asthenia. In many of these cases it

was very difficult to get the employees to take treatment. Their whole attitude was characterized by a great indifference to everything. Promises made were frequently not kept. One man who had five children would sit by the fire entirely indifferent to the state of his family needs. There is no doubt that the Spirochaeta pallida takes away the energy of many workmen, and from being useful citizens they come to lead a vegetative type of existence which is incompatible with industrial efficiency. The whole picture of a syphilitic asthenia is that of an individual who is entirely insensitive to his own, to his family's, and to industrial needs.

The sexes were divided as follows:

Males	married	97
	single	48
Females	married	20
	single	11
		176

Of the married males, only five could be persuaded to bring their wives for a Wassermann test. Of these five, two were negative and three were positive. Curiously enough, the wives did not take enough interest to want to know whether they had the disease, for it is certain that most of them knew that their husbands were under treatment. Of the eleven unmarried women, one was married three days after the fourth dose of salvarsan. Treatment followed the nuptials, and she later gave birth to a healthy child.

One patient committed suicide. Four became insane. One died of uremia following a drunken debauch.

As to previous treatment, 37 cases had had treatment; 139 had never had treatment. Two had been treated in the English Army, 1 in Constantinople, 1 in Buenos Aires, 2 in Edinburgh, 1 in Naples, and 1 in Hamburg; 1 was treated early in a public dispensary. Only 9 were actually receiving treatment at the time we made the discovery. It is believed that 5 cases were hereditary. From the public health point of view, this shows how inadequate the follow-up is in the ordinary case of syphilis.

Every one of our employees who is known to have syphilis is now receiving treatment. We do not give such treatment at our dispensaries, but refer the individual to his own physician, to a specialist, or to a clinic. There is a syphilis register, and each case is followed from year to year. Without this register, and without this follow-up treatment, who can say what these cases would have cost industry in complications if treatment had not been instituted?

It is not our policy to discharge a man who has syphilis. If such were the case, it would soon become impossible to get the Wassermann reaction of anybody. There is the greatest effort at co-operation, and every encouragement and assistance is given the employee to get treatment as quickly as possible and at rates compatible with his financial condition. The public clinics in the city have proved a great help in this work.

That the patient frequently does not realize the value of this type of service is shown by the fact that eighteen employees quit within three months rather than submit to the follow-up; six others never reported for work at all. In other words, out

of 176 cases, twenty-four, or 13 per cent., preferred no treatment at all and left rather than be reminded that treatment was necessary. The turnover in syphilis is tremendous under the best of circumstances. One wonders what the future will be in eradicating this disease when such a large percentage will not take treatment at a price which hardly covers the cost of the medicine. Of those discovered, not over 15 per cent. had previously received anything like adequate treatment or follow-up.

If, however, all physicians in industry will tackle this problem earnestly, there is little doubt that great progress will be made. The Wassermann reaction will be popularized in the family as well as with the patient. More cases of syphilis will be taken care of; and may there not gradually develop a changed attitude on the part of employees in reporting the disease? Constant hammering will bring results. Industrial medicine offers an unusual opportunity to discover the disease, and, above all, the follow-up becomes relatively easy when the patient remains in the company's employment.

In those communities in which there are no public clinics and no adequate facilities to adjust charges to the financial condition of the patient, it is the authors' feeling that a clinic could be established in the company at no great expense. The results, it is believed, would pay for any cost which would be attached to this type of service.

Summary

1. It is possible with a proper technic to get many Wassermann reactions in industry with comparative ease.

2. Early treatment of syphilis is the best preventive of complications following accidents, and periods of disability are thus cut down. There is a reduction in sick benefit payments for the same cause.

3. A perfect follow-up system is possible as long as the employee continues his employment.

4. The work has three aspects: It is a protection to the individual, to public health, and to industry.

5. Blood was taken from 3,447 individuals. Between 3.5 and 4 per cent. gave positive reactions.

6. Syphilis is costly to industry and to the state; the taking of more bloods will help greatly in reducing the incidence of syphilis in the community.

A CLINICAL AND LABORATORY INVESTIGATION OF THE EFFECT OF METALLIC ZINC, OF ZINC OXIDE, AND OF ZINC SULPHIDE UPON THE HEALTH OF WORKMEN*

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* Received for publication May 15, 1926.

I. INTRODUCTION

THERE exists in the literature no thorough clinical and laboratory study of a group of workmen exposed over considerable periods of time to uncontaminated zinc compounds. Subjects for such a study are limited, since zinc ores in most parts of the world are heavily contaminated with lead and usually contain also, in varying amounts, arsenic and cadmium. Western American ores contain lead, cadmium, and occasionally arsenic. Foreign ores contain these three toxic sub-

stances and sometimes antimony as well, the amounts varying in the different ore fields. These contaminating substances are readily carried along with zinc in the process of smelting, and constitute, therefore, a common menace to zinc workers. The existence of these toxic substances in zinc ores has been the occasion of great confusion in the literature in regard to the physiologic action of zinc, and has made very difficult the problem of determining how far illness among zinc workers is actually due to zinc.

An exceptional opportunity for studying the effect of uncontaminated zinc compounds on the health of workmen exists, however, among men employed in the manufacture of zinc products made from New Jersey ores, since the zinc ores from this region are very unusual in having in them an amount of lead so low as to be practically negligible. Table 1 contains typical analyses of zinc ores from various parts of the United States. The high lead content of most of the western ores as contrasted with the extremely low lead content of the Franklin, N. J., ore is striking. Some of the western ores are relatively low in lead but the sizes of the ore fields in which this low lead ore exists are small in comparison with the large field in New Jersey. Western ores are also high in cadmium as compared with Franklin ore.

Zinc ore handled in the New Jersey Zinc Company plants at Palmerton, Pa., where this study was made, is, in the main, New Jersey ore and is practically free from lead and low in cadmium. In the manufacture of certain brands of zinc oxide used in the paint trade and in the manufacture of lithopone, however, leaded western ores are smelted in Palmerton and leaded oxide is collected in the collecting cylinders in certain of the bag rooms and is subsequently packed. All leaded operations—smelting, oxide collecting and packing—are, however, carefully segregated at one end of plant A. As soon as a man is assigned to a leaded operation, his name is automatically sent to the Company physician and, as long as he continues at this work, he is subjected to a monthly physical examination in order to anticipate and to prevent the development of trouble from lead. Thus, a check is maintained upon the lead factor as a cause of illness among our men. Leaded zinc oxide constitutes approximately 11 per cent. only of the total output of zinc oxide from the Palmerton plant. In the main, our men are exposed to relatively uncontaminated zinc and the situation in Palmerton represents, therefore, an excellent opportunity for studying the effect on workmen of zinc itself, uncomplicated, for the most part, by possible effects of other substances known to be toxic.

This exceptional opportunity for studying zinc as an industrial health hazard has recently been made even more exceptional as a result of the development by Lutz (1) and Fairhall (2) of very delicate and accurate methods for determining zinc in biologic materials, and as a result of the establishment of the fact by these authors[1] and others (Rost and Weitzel (3)) that zinc is normally excreted in both urine and feces.

[1] Unpublished data. Personal communication.

TABLE 1.—THE HEAVY METAL CONTENT OF ZINC ORES FROM VARIOUS PARTS OF THE UNITED STATES

Ore Field	Zn	Pb	Fe	Mn	Cd	Cu	S	As
	%	%	%	%	%	%	%	%
1. Unroasted sulphide ores:[1]								
Leadville district, Colo.	20.80	6.30	17.47	0.41	0.19	0.11	26.46	0.04
	13.70	7.20	25.69	0.28	0.13	0.11	34.59	0.01
	16.10	12.90	23.22	0.26	0.13	0.06	32.65	0.01
Kelly, N. M.	17.20	7.10	18.09	0.48	0.06	0.49	18.16	....[2]
	16.20	6.70	18.34	0.21	0.09	0.71	17.92	....
Silver City, N. M.	23.20	0.90	20.88	0.74	0.11	0.41	27.17	....
	26.30	0.11	19.30	0.67	0.10	0.86	27.15	under 0.01
Austinville, Va.	42.70	16.00	4.30	.....	0.11	....	27.64	under 0.01
Tristate district, Okla.	60.30	1.20	0.69	.....	....	....	29.57	....
2. Roasted sulphide ores:[1]								
Leadville district, Colo.	22.40	12.40	23.00	0.12	0.18	0.17	4.71	0.03
	34.70	4.20	20.92	0.51	0.13	0.13	5.60	....
	23.70	6.60	29.34	0.17	0.18	0.11	7.19	0.09
Breckenridge, Colo.	51.10	1.90	11.41	0.38	0.27	0.11	5.50	....
Miscellaneous western ores milled at Cañon City, Colo.	47.30	2.80	9.76	0.26	0.33	0.71	4.70	....
Wisconsin district	67.70	0.30	2.91	0.10	0.14	....	4.08	under 0.01
Hanover, N. M.	43.90	0.65	7.40	0.67	0.16	0.15	5.57	0.00
Joplin district, Mo.	69.70	0.66	1.48	0.05	0.49	0.08	1.93	....
3. Oxidized western ores:[1]								
Chaffee County, Colo.	28.40	7.80	9.40	1.30	0.08	0.18	1.10	....
Good Springs, Nev.	22.20	19.20	1.10	trace	....	....	0.60	....
	37.20	5.00	3.00	0.06	0.20	0.07	0.39	....
4. Franklin ores, Franklin, N. J.:								
Franklinite "A"	17.40	under 0.05	33.60	12.90	under 0.01	....	0.33	0.02
Franklinite "B"	16.40	under 0.05	38.50	12.10	under 0.01	....	0.26	0.03
Franklinite No. 1	16.60	under 0.05	36.80	6.40	under 0.01	....	0.25	0.02
Franklinite No. 2	18.60	under 0.05	29.60	7.45	under 0.01	....	....	....
Franklinite "Half and Half"	16.31	0.06	15.33	14.30	0.02	....	0.14	0.03

[1] In the unroasted sulphide ores, the metals are present essentially as sulphides. In the roasted sulphide ores, the metals are in combination essentially as sulphides, oxides, or sulphates. In the oxidized ores, there are essentially carbonates, oxides, or silicates, with or without small amounts of sulphides.

[2] Blank indicates that no analysis was made.

The investigation reported in this paper was undertaken, therefore, with the idea of subjecting twenty-four workmen who had been exposed to zinc for considerable periods of time to a comprehensive clinical and laboratory study, in order to determine the amounts of zinc which they were inhaling, absorbing, and excreting, and whether or not this metal was causing damage which could be detected clinically or by laboratory tests.

With the exception of a brief paragraph on its incidence among our series of workmen, we shall not include in this study any discussion of metal fume fever (brassfounders' ague, zinc smelters' chills, "spelter shakes," etc.). The weight of opinion at the present time (Lehmann (4), Drinker (5)) inclines to the view that this acute febrile reaction, following the inhalation of freshly generated and, therefore, very dry and finely dispersed zinc oxide particles with little tendency to settle out until they reach the alveoli, is dependent on the absorption of proteins from alveolar epithelial cells damaged or destroyed by the oxide particles, and not on the absorption of zinc itself. The fact that similar phenomena may occur, in the opinion of various observers, as a result of the inhalation of other metals (copper (6), nickel, iron, cobalt, cadmium (7)), is suggestive evidence that zinc is an incident in and not the ultimate cause of the event. This conclusion is supported by the fact that the particular symptom-complex of metal fume ague never occurs from the absorption of zinc by any other route or in any other form.

There are other features in the composite picture of zinc ague which tend to bear out Lehmann's protein absorption explanation. Among these, are the apparent tendency on the part of exposed persons to develop an immunity to the reaction, and the fact that the symptoms are such as have never been observed in metallic poisoning but resemble those of a bacterial infection. And yet the disturbance cannot be a true bacterial infection since it lasts only a few hours, is never dangerous, and never leads, as a true infection occasionally would, to pneumonia, pleurisy, etc. That the symptoms of metal fume fever "are invariably associated with zinc (or brass) only is," as Hayhurst (7, p. 331) says, "simply a trade-process circumstance, due to the low boiling point, excessive volatility, cheapness and therefore waste of zinc to the air."

II. Review of the Literature

Reports on the health of zinc workers and on the hazards of zinc began to appear in the literature about 1850. Landouzy and Maumené (8) in that year described an affection which they called *intoxication zincale* occurring among workers who breathed, and undoubtedly swallowed, zinc oxide and zinc carbonate dust while cutting, twisting, and packing galvanized-iron wire coated with these compounds. This was long ago and the work and working conditions were very primitive. After being cut, the wires were put into packages, beaten with a piece of wood to straighten them, and then fastened into bundles. The laborers had been engaged in this work for from eight to fifteen years with no appreciable trouble, when suddenly

the ordinary wire was replaced by galvanized wire which—the process of galvanizing being new—was covered with a thick layer of zinc oxide and zinc carbonate dust, which escaped freely during the handling of the wire and especially during the beating of the packages. (The authors noted at this point that there was no trace of lead in the dust. Whether they were able to detect it or not is a debatable matter, especially as we now know that practically all of the early zinc oxide contained lead. Pure zinc was not a commercial product in 1850.)

Very soon (three in six to eight days; one in fifteen days; two in three to four weeks) after the introduction of the galvanized wire, the workers were seized with troubles which the authors felt it was "impossible not to relate to the action of the zinc dust." Four out of six workers felt a general depression, shivering, headache, anorexia, marked thirst, severe pain in the throat with dysphagia, pain in the jaw and laryngeal region, a considerable swelling up of the tonsils with ulceration, redness of the palatine arch, whitish film on the gums, salivation, fetid breath, and finally colic and diarrhea. One worker had only colic and diarrhea; with another, the colic was accompanied by nausea, tenesmus, and obstinate constipation. The symptoms disappeared when the workers stopped using zincked wire and did not reappear when they were given galvanized wire but without any coating of dust.

The early symptoms of subacute arsenical poisoning are nausea, vomiting, and diarrhea (may be absent), great thirst, pain in the epigastrium, and painful deglutition accompanied by spasmodic constriction of the pharyngeal muscles. In slow poisoning there may be salivation, sore and at times even lacerated gums, and inflammation of the pharynx. This description strikingly resembles the condition which Landouzy and Maumené ascribe to zinc oxide.

Bouvier (9), in a paper entitled "Poisoning by Oxide of Zinc (Zinc Colic)," reported, also in 1850, the case of a cooper, 42 years old, who had been employed four months at Asnières with five other coopers putting bottoms on barrels filled with zinc white. The men were then put at the task of repairing barrels which had already been used—a task which kept them constantly in a dusty atmosphere. At once they began to feel pain and distaste for their food. Wine and brandy which they drank to stimulate their appetites were distasteful to them and did not take away the pasty taste which was constantly in their mouths.

Bouvier's patient continued this work only two days. He vomited, had violent pain and constipation. These symptoms grew worse in the five days before he entered the hospital; he suffered so much that he rolled on the floor of his room. He had no bowel movement for five days. His tongue was white, his appetite lacking, and his sleep poor, but he had no fever. Recovery occurred following treatment with 40 to 80 cg. of gamboge per day and baths.

A second patient, aged 22, came to Bouvier with intense headache, injected face, giddiness, nausea, vomiting, diarrhea, severe epigastric pain, weakness of the legs, some itching of the skin, and reddish pimples. He

had been working at the zinc factory in Asnières for five months cleaning the upper opening of zinc retorts. The workroom always contained some zinc vapor. The patient in the past had often felt fatigue of his limbs, lack of appetite, and diarrhea, but a day or two of rest had hitherto always cured him. All the workers were subject at one time or another to this group of symptoms. Many of them suffered also from vomiting, diarrhea, headache, and weakness of the limbs; even carpenters making repairs became affected.

Among other remedies administered to this patient, baths were given, and the bath water subsequently analyzed for zinc, lead, copper, and arsenic. This bath water contained zinc but no copper or lead; one test for arsenic indicated faint traces. The acceptance of the finding of zinc in the bath water of patients working in a zinc factory as evidence of zinc poisoning is so ingenuous that we cannot resist mentioning it.

The acute symptoms, especially in the second case, described by Bouvier, are very suggestive of acute arsenical poisoning—vomiting, diarrhea, headache, giddiness, muscular weakness, sensory disturbance (itching), and the presence of pimples—while the weakness, languor, loss of appetite, some nausea and vomiting, and diarrhea (this may be absent or constipation may occur), occurring among all the workers at one time or another, are the very symptoms one finds in the first stage of chronic poisoning from arsenic.

Even in 1850, reports that cases such as these were due to zinc received some challenge. Chevallier (10) entered into a controversy with Bouvier in regard to his first patient, Chevallier maintaining that this man had had gastric trouble before he ever worked in a zinc factory. Chevallier also urged the introduction of zinc white in preference to lead white as a great hygienic improvement. Later medical writers, notably Pera (11) in 1911, have also urged the use of zinc oxide instead of lead carbonate in paints because of its advantages from the point of view of health.

The vast bulk of published material dealing with zinc as an industrial hazard is concerned with the question of metal fume fever but there exist also in the literature descriptions of a condition characterized by vomiting, intestinal colic, constipation, anemia, emaciation, and sometimes by muscular paralyses with eventual atrophy—a chronic condition frequently ascribed to zinc. Sacher (12), for example, reviewing the subject of so-called chronic zinc poisoning, described the condition as a chronic general intoxication following the inhalation of zinc oxide dust, and a disease to be sharply differentiated from the acute zinc fever resulting from the inhalation of hot zinc fume.

As instances of chronic disease caused by zinc, Sacher cited Bouvier's (9) cases of "zinc colic," and the *intoxication zincale* described by Landouzy and Maumené (8). Sacher's discussion of so-called chronic zinc poisoning continued with an account of a case reported by Popoff (13) of a man employed for twelve years in a bronze casting house in whom symptoms of poisoning appeared, especially in winter. These consisted in vomiting after the taking

of food, heartburn, acid eructation, at times severe diarrhea with colic and pains in the extremities, especially in the calves. Sometimes six to ten days of constipation occurred with dull pain in the region of the navel. Gradually a high degree of mental depression developed and with general exhaustion came paresis of the right leg and right hand. The mucous membranes were pale, the skin brownish gray and inelastic, and the body musculature partly atrophied, especially on the right side of the face and the extremities of the same side. Tactile sense was affected on the same side, with an increased feeling of itching. "That these phenomena should be conclusively ascribed to the influence of zinc, and that it was a question of chronic zinc poisoning, was proved by the detection of zinc in the urine." This conclusion of Sacher's is one which occurs frequently in the early literature on zinc. If zinc was present in the urine—and we need scarcely remind you that we now know that zinc is normally always present in urine—the symptoms observed must be due to zinc. The possibility occurred to only a few that even if zinc were present in the urine some other agent may have been the trouble maker. Later commentators, notably Tracinski (14) and Kobert (15), attributed Popoff's disease and a similar condition reported in 1879 by Schlockow (16) to lead poisoning.

Sacher's account of chronic illness attributed to zinc referred to Hirt who observed several zinc oxide workers who had become cachectic and suffered from weakness, loss of weight, and especially from a severe stomach or intestinal catarrh. "Husemann," however, said Sacher, believed "that the union of zinc with lead (to 3.3 per cent.) and arsenic (0.19 per cent.) was guilty of the injurious effect of zinc oxide and zinc fumes."

Murray (17) has described a chronic condition among brass workers—an illness consisting of anemia, dyspepsia, nausea, vomiting, palpitation, thirst, colic, diarrhea, loss of weight, green sweat, cough, green line on the gums, and eczema. Murray himself was inclined to attribute this condition to copper, although he was of the opinion that zinc could not be ignored. In this connection, Hamilton (18) has reminded us that brass workers may have to breathe the fumes of acid from the pickling tubs, and of volatile solvents from shellacs and lacquers; that they are exposed to great heat from the crucibles; and that they may get dermatitis from the antimony and acute arsenical poisoning from the gas generated if metal contaminated with arsenic is put in the pickling tank.

Kobert (15, pp. 397–398) concluded his discussion of so-called chronic zinc poisoning in his "Textbook of Intoxications" as follows: "According to Wutzdorff's [(19)] comprehensive collection there is in the zinc foundries indeed poisoning by lead, hydrogen sulphide, sulphurous acid and carbon monoxide; but one certainly depending on zinc could not be ascertained. How little poisonous zinc must be appears to me from the fact that those sent to me with tuberculosis to Görbersdorf from the Silesian zinc foundries, after three months' stay in the Bremen sanatorium still excreted zinc and showed no chronic zinc poisoning except anemia."

Following protracted zinc feeding experiments on animals, Lehmann (20) wrote: "Of a chronic zinc poisoning in my research I have seen nothing further than gastric variations, which one may perhaps regard, but scarcely with cogency, the results of a chronic gastric catarrh, and certainly no general symptoms. I could see no injury to the kidneys. Also I could not observe, in spite of large doses, chronic zinc poisoning in the sense of a general injury to the body."

Von Jaksch (21, pp. 167–168) in his book on poisons published in 1910 stated that: "The question whether a chronic zinc poisoning really exists which is accompanied by anemia, dyspepsia, and a series of nervous disturbances, such as ataxia, anesthesia, and paresis, is not fully solved. Very well-known authors deny absolutely the existence of a symptom-complex of this sort."

Seiffert (22) in 1918 published a long article dealing with "The Share of Lead and Zinc in the Zinc Plant Sickness, with Remarks on Hygienic Measures in Zinc Plants." In zinc plants, according to this author, the so-called zinc plant sickness often occurred. It consisted in a pallid appearance, loss of weight, failing strength, stomach and bowel troubles, nervousness, bluish tint of the gums, pains in the joints; often paralysis and muscular degeneration, etc., also occurred. But all these symptoms did not occur together in every case. Lead, to the poisonous effect of which the zinc worker was constantly exposed, had a prominent part in the origin of the sickness, but according to Seiffert it was not the only cause of the sickness, as had been generally assumed till very recently. Seiffert expressed the opinion that other metallic poisons besides lead were responsible for the sickness, especially zinc, which, he said, had been generally considered harmless.

Seiffert found zinc even more frequently than lead in the urine of 69 sick workmen whom he examined. Forty of these men (58 per cent.) proved to have metals in their urine; 25 (36.2 per cent.) had zinc only; 2 (2.9 per cent.) had lead only; 13 (18.8 per cent.) had both zinc and lead. Thus 38, or 55.1 per cent., had zinc, and 15, or 21.7 per cent., had lead. There were only 2 cases among those in which lead was detected in the urine, in which lead poisoning was certainly present; there was only 1 case among the 15 in which the general symptoms of chronic illness were especially prominent and severe. Zinc was superior to lead not only in the number of cases, but also in the quantity of the metal found in the urine. Disregarding the cases in which the quantity of metal excreted was too minute to weigh, there was on an average 3 mg. of zinc per liter of urine, but only 0.16 mg. of lead. Seiffert rejected the objection that small quantities of lead could have a more dangerous effect than large quantities of zinc; he rather thought that the human body had a great power of tolerating or resisting lead.

The zinc which reached the body in the form of dust Seiffert regarded as the chief enemy which constantly harmed the zinc worker. The constant, though slight absorption produced the sickness gradually. He believed that zinc accumulated in the body and was excreted long after the

man had been removed from work in zinc.

The fallacies in Seiffert's reasoning are very obvious. To attempt to evaluate, by a process of elimination, the part zinc plays in illness among men known not only to be exposed to lead but many of them to be actually excreting lead or to be suffering from recognized lead poisoning, is clearly unjustifiable. To lay great stress, as evidence of zinc poisoning, on the presence of zinc in the urine of zinc workers, and to infer large deposits of zinc in the body from the finding of this metal in the urine of men months after removal from zinc work—these inferences lose their value as convincing evidence of zinc poisoning, when one knows that zinc is normally excreted in urine in amounts up to 1.75 mg. per day.

Stepp (23), writing in 1917 and taking his statements largely from textbooks, gave a number of brief references to the existence or nonexistence of a chronic disease caused by zinc. Among these are the following: "In Eulenberg's scientific encyclopedia (Möller) one may read . . . . 'Chronic poisoning has never been observed, although opportunities for the taking up of zinc have not been lacking: there are zinc water pipes, preserving cans, zinc vessels; if zinc workers become ill, the reason is to be sought in contamination of the zinc.'

"On the contrary, Grätzer in *Der Praktiker* writes, ... 'One occasionally encounters chronic zinc poisoning, which manifests itself in vomiting, intestinal colic, obstipation, emaciation, anemia; sometimes muscular paralysis occurs, eventually with atrophy.'"

Commenting on these quotations, Stepp wrote: "While the communications of Möller concerning the poisonousness of zinc sound unqualifiedly negative, the results of Grätzer are absolutely positive."

This statement, to our minds, pictures very well the confusion which exists in the literature in regard to the existence or nonexistence of a chronic disease caused by zinc. But why does this confusion exist? In our opinion, a variety of reasons contribute to it. The very common contamination of zinc ores with lead, arsenic, cadmium, or antimony and the failure of investigators to recognize the parts that these different substances played in the disease picture which they were studying; the readiness, even when contamination was admitted, to ascribe disease to zinc because there was more zinc than anything else; the very prevalent idea that the finding of zinc in urine was a proof of poisoning by zinc; the stating and restating in the literature of conclusions, often erroneous, emanating from one or two observers, but repeated in reviews and in textbooks by other men until they became authority—these are some of the reasons for the conflicting evidence in the literature in regard to so-called chronic zinc poisoning.

The importance of lead and of arsenic in the industrial poisoning of both zinc and brass workers has been stressed by many writers besides ourselves—Nowak (quoted by Helpup (24)), Husemann (quoted by Sacher (12)), Tracinski (14), Sicard (25),

Wutzdorff (19), Hamilton (18), Hayhurst (7), etc. Stephens (26) has presented evidence in support of the idea that cadmium is responsible for digestive disturbances among spelter workmen. A certain number of observers are unequivocal in their belief that a chronic disease caused by zinc alone does not exist. Tanquerel des Planches (27), for example, in a thesis on occupational intoxications from copper, zinc, and mercury wrote: "We conclude for zinc as for copper that there exists no occupational intoxication, properly speaking, of zinc, and that the accidents observed have been due to the impurities which this metal may contain (lead, arsenic, antimony, etc.), or to the elevated conditions of temperature necessary for its founding." De Pulligny (28), in a report presented at the Tenth International Congress for Hygiene and Demography, expressed the opinion that an occupational poisoning by zinc, properly speaking, does not exist and that any illnesses resulting from work with zinc should be attributed to the circumstances of the work or to toxic impurities (lead, arsenic, etc.). In the discussion of this paper, Glibert (see de Pulligny (28)) added that it had been proved in the numerous zinc factories in Belgium that there is no poisoning by zinc, very little by arsenic, but much by lead.

Hayhurst (7, p. 333) in his section on zinc and the zinc industries in Kober and Hayhurst's "Industrial Health" wrote, "the physician must get away from the idea of attempting to diagnose chronic zinc or brass poisoning, as there probably is no such condition. Rather, look to lead, arsenic or manganese for the specific causes of such conditions."

McCord and Friedlander (29) in a recent article have reported the occurrence, in a small galvanizing plant, of widespread gastro-intestinal disturbances, varying from gastro-enteritis in younger workers to what were considered well-established gastric and duodenal ulcers among workers employed for a long time. These authors, although they accept various other substances as possible contributing factors, nevertheless "attach significance to zinc as a causative agent." The three chief arguments which McCord and Friedlander present in support of their belief that zinc is a causative agent in the condition they describe are: a demonstration of the formation of zinc sulphate and zinc chloride at levels and under conditions that involve exposure on the part of the workers; the fact that "in workers whose urine has been tested, zinc has been found in quantities in excess of accidental urine content from food, galvanized iron pipes, etc.;" and the close resemblance which they find between their observations of lesions among zinc workers and reports in the literature on the results of experimental work with zinc.

In our opinion, the evidence presented against zinc in this paper is hardly conclusive. The authors were unfortunate in having to deal with a group of unintelligent men who were not co-operative and it was, therefore, impossible for them to obtain adequate clinical or laboratory evidence of the existence of the gastric and duodenal ulcers which they suspected. In view

of our own finding that men can absorb zinc through both the respiratory and the digestive tracts and excrete it along the gastro-intestinal canal for years without any evidence of gastro-intestinal disturbance, we are inclined to feel that all other possible causative agents must be more rigidly excluded before zinc is incriminated in the industrial situation which is pictured by McCord and Friedlander in their paper.

The finding which these authors report of zinc in the urine of workers "in excess of accidental urine contact from food, galvanized iron pipes, etc.," is an interesting point upon which we should like to see the actual figures obtained by the authors. The amounts of zinc normally and constantly present in urine are far from negligible. This fact and the observations which we have made on the very considerable quantities of zinc which appear in the urine of zincked animals and of zinc workers, none of whom show any evidence of any sort of ill health, have led us to the conclusion that the presence of zinc in urine is not a significant diagnostic circumstance.

One further suggestion should perhaps be made in a discussion of McCord and Friedlander's paper. The experimental evidence in the literature which they cite is all prejudicial to zinc, whereas, as a matter of fact, there is a large mass of experimental evidence reported indicating that zinc is not toxic, and that ill health associated industrially with zinc is in all probability due to toxic impurities in the zinc ores—lead, cadmium, arsenic, antimony.

We have reviewed at some length the literature on the health of zinc workers in order to show the confusion that exists in regard to zinc as an industrial hazard, and in order to illustrate the various factors of error which have been the sources of this confusion. We hope in the following account to clear up the situation somewhat by presenting the results of a detailed clinical and laboratory study on men exposed industrially to relatively uncontaminated zinc, and one in which advantage has been taken of new and delicate methods of analysis for zinc in biologic materials and of recent information in regard to the normal zinc metabolism.

III. Selection of Subjects and Industrial Processes Represented

The New Jersey Zinc Company plant in Palmerton, Pa., where these studies have been carried out, employs at the present time approximately 1,620 men occupied in the manufacture of or in research work on zinc products. These men are engaged in smelting zinc ore for spelter and for zinc oxide; in the rolling of sheet zinc; in the various processes of manufacture of zinc oxide (used especially in the rubber and paint industries), of lithopone (a barium sulphate-zinc sulphide pigment, containing approximately 30 per cent. zinc sulphide), of various zinc salts as a by-product, and of blue powder or zinc dust (fine metallic zinc used in the dyeing industry); and in investigative work on zinc and its products.

In the selection of men for this

study, the department chiefs were requested to choose at random long-time employees engaged in typical stages of operations in the plant where there was the most intensive exposure to the highest concentration of zinc containing materials. Men were selected, therefore, from the so-called bag rooms, the zinc oxide packing houses, the French process zinc oxide plant, the blue powder or zinc dust plant, and the lithopone packing house.

1. Zinc Oxide Bag Rooms

In the so-called bag rooms, zinc oxide in suspension, together with heated air and gases from the furnaces, passes under positive pressure into vertical cotton cylinders, approximately 39 to 42 feet in height by $22\frac{1}{4}$ inches in diameter. A filtration of the mixture coming from the furnaces takes place, leaving the zinc oxide collected upon the inner surface of the cotton cylinders or bags. These bags are shaken in series according to a schedule which requires that each bag shaker be engaged in shaking for an approximate total of two and one-half hours in the course of an eight-hour shift. The bags are shaken by hand at various levels and the released oxide drops into collecting bags at the bottom of each cotton cylinder. When the collecting bags are full, they are changed for fresh ones. Between shaking operations the men are usually found on the lower floors doing light work or resting.

In this study, twelve men, chosen from several different bag rooms, were examined. In all of the bag room buildings the process of zinc oxide collection is, at this stage, essentially identical in principle but the character of the product, the building construction, and the ventilation differ to some extent.

Eleven of the twelve men are bag shakers, their work consisting in shaking the long cotton filter bags, removing loaded collecting bags, repairing "boofs" or leaks in the bags with patches, when necessary replacing bags that have failed, and sweeping and cleaning up oxide scattered around the hoppers. The work of the twelfth man consists in tapping on the sheet iron branch pipes and headers and sheet iron hoppers, which connect the furnaces with the filtering bags, in order to loosen the oxide clinging to the inside of the pipes and hoppers. This tapping constantly stirs up old dust which has settled upon the pipes from the general dust in the room. The job is, consequently, an unusually dusty one, as jobs in the plant go. This subject, in addition to tapping, occasionally shakes out filtering bags and bundles them. Since this man (No. 4) has worked thirty-five and one-half years for the Company and since his job of tapping is a very dusty one, we regard him as an excellent instance of long-continued and maximum exposure (in the Palmerton plants) to zinc oxide dust, and have, therefore, chosen him as one of the men whose hospital case report is given in full. The case report of Subject 19, a bag shaker in oxide plant A and also a worker on the zinc sulphide block, is likewise given in full.

All of the bag house men report wearing respirators part of the time—

presumably during the dustiest part of their operations.

2. Zinc Oxide Packing Houses

The receiving bags full of zinc oxide are hauled by truck to the packing houses, separate buildings where the product is screened, graded, and packed into bags or barrels. While these operations are largely mechanical, the operators are stationed close to the machines and breathe an atmosphere in which there is a considerable quantity of zinc oxide in suspension. Five of the men in this study work in the oxide packing houses, two of them removing loaded bags from the trucks and pouring the oxide out of bags into the hoppers. One of the packing house men sweeps up floors and cleans up around the bolters (machines for screening the oxide); a fourth shakes out used collecting bags from the bag house—very dusty work—and repairs them; while a fifth man serves as a helper, lending a hand wherever needed.

With the exception of Number 5, who wears a respirator while shaking out bags, these packing house men report that they seldom or never wear respirators.

3. French Process Zinc Oxide Plant

Two men from the French process zinc oxide plant were included because it was anticipated that a somewhat higher atmospheric content of zinc oxide probably existed there than in the other two oxide plants, details of the bag rooms and packing houses of which have already been given. One of the men from the French process plant mixes with a shovel different grades of zinc oxide in a large box, and then shovels the mixture into an elevator—very dusty work. The second man is a reheater man. His job is to receive into pans oxide which has gone through the reheater.

Neither of these two men wears a respirator.

4. Blue Powder or Zinc Dust Plant

In this plant the finely divided metallic zinc (blue powder) is collected into open trays from vertical condensers and transferred for screening and packing. This operation is not a particularly large one but is, nevertheless, fairly constant. Six men are employed at it daily. Two of the men whom we have studied clinically work in the blue powder plant. One of them charges retorts, draws out blue powder, fires the furnaces and muffle kiln, and cleans the fires, removing ashes and wheeling in coal. The second man works part of the time with the blow-out crew, blowing dust and refuse out of the flues under the spelter furnaces. The rest of the time—two to three hours a day—he screens zinc, partly by hand, partly by machine. Since screening blue powder is the dustiest part of the operation in the blue powder plant, this man (No. 1) has been selected as one of those whose case report is given in full.

Subject 1 wears a respirator most of the time, while his companion in the zinc dust plant wears one only on days of high wind.

5. Lithopone Packing House

Here is screened, graded, and packed lithopone, a barium sulphate-zinc sul-

phide pigment, prepared by a process which, until the product reaches the packing house, involves the handling of moist materials only. Men were included from this type of operation in order to obtain information concerning the possible variations of the effect of zinc when it is absorbed as a sulphide rather than as an oxide. The possible influence of the barium salt in the combination must, however, be taken into consideration, and the fact that only 30 per cent. of the pigment is zinc suphide.

Three workers from the lithopone packing house are included in our study. One of them sees that the lithopone is carried on conveyors to the bolters, and cleans up around hoppers and bolters. Two others work as packers, handling, emptying, and loading barrels and bags of lithopone, and heading barrels.

The three lithopone men report that they do not wear respirators.

IV. Zinc Concentration in Air in Parts of Plant from Which Subjects Were Selected

In order to determine as exactly as possible the amounts of zinc to which our various workers were exposed, determinations were made of the atmospheric concentrations of zinc in various parts of the plant, typical of the working places of each of the twenty-four workmen studied. The dust sampling apparatus employed was a type of electric precipitator, first used and described in detail by Drinker, Thomson, and Fitchet (30); the dust samples were collected, in the manner described in their article, by R. M. Thomson, one of the developers of the apparatus; and, finally, the dust samples were analyzed for zinc in the laboratory of the Department of Ventilation and Illumination of the Harvard School of Public Health. The collection of samples was made under varying weather conditions, but, on the whole, the samples represented fair averages of the dustiness to which the various workers are usually exposed.

The samples in all cases were taken as close as was practically possible to the operation which was being studied—in all except two cases, within 4 feet; in most cases, nearer still. In one of the exceptional operations, that of shaking out long oxide collecting bags against a standard, the investigator was forced to stand about 8 feet away from the operator (Subject 5) while taking his sample. In the other exceptional operation—the screening of blue powder—the sample was taken 5 to 6 feet from the operator (Subject 1). The actual maximum zinc concentrations to which these two men are exposed are, therefore, probably slightly higher than the figures given. Since this investigation is concerned with the effects of zinc, no attempt was made to determine the actual dust content of the air. Although in all cases organic and other inorganic matter was present, the results of the air analyses are given throughout in milligrams of zinc per cubic foot of air.

Chemical analyses of the samples for zinc were made under carefully controlled conditions, either by titration with potassium ferrocyanide, uranium acetate being used as an outside indicator, or by turbidimetry with potas-

sium ferrocyanide. The procedure was as follows: Each sample was made up to definite volume; one-half of each volume was evaporated to dryness, and by the amount of residue left it was judged whether titration or turbidimetry should be used. If titration was used, the other half of the sample was reserved as a check; if turbidimetry was used, the half portion was, in most cases, sufficient for duplicate analysis. In no case was a single analysis of a sample taken as a final result. The following is a brief summary of the results obtained from the dust sampling tests.

1. Settling Test in Bag House

This test was undertaken to obtain some idea of the concentrations of zinc to which bag house men, employed on bag shaking, are exposed during a complete cycle in shaking the bags of one block on one floor. The period of time elapsing between shakes on a floor is usually four hours. The test was timed to begin with the start of the shaking on one block and was continued until the next shake was made. The sampling apparatus was set up in the center of a block, which consists of ten rows of bags, and left in this position throughout the test.

As will be seen from Figure 1, the concentration of zinc in the air is highest during the periods of shaking; falls off rapidly after the shake; rises again, owing to shaking in the same block on the floor above; and then falls off again until another shake is made on the same floor. It appears from the results that the more rapid and vigorous the shaking, the higher will be the zinc concentration breathed. Assuming that conditions in the block on which this settling test was made are representative of this particular bag house, the operator would be exposed to a concentration of

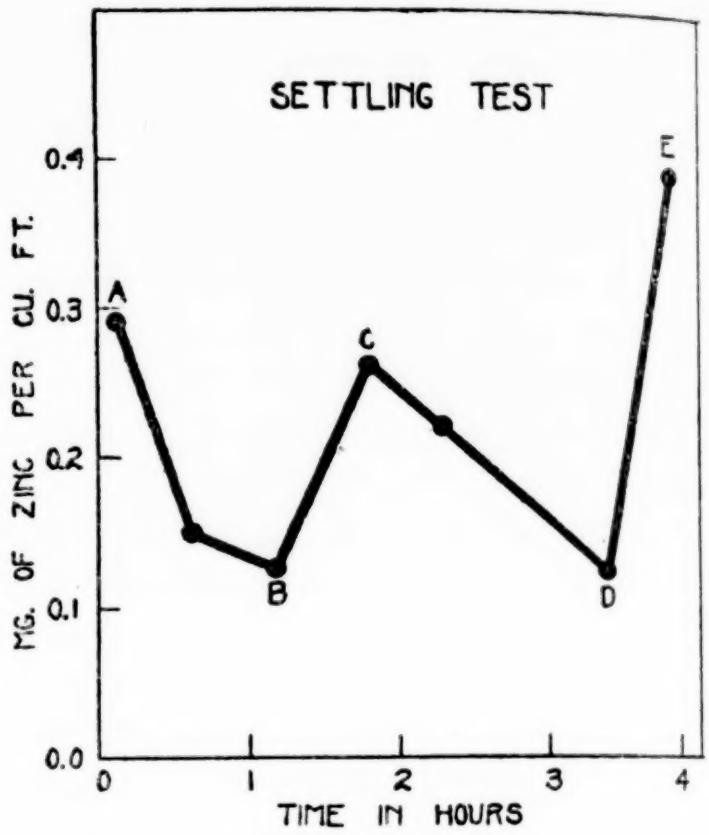

FIG. 1.—Zinc oxide settling test in bag house, oxide plant B. A, 11:07 A.M., during shake of seventeen and a half minutes; B, 12:10 P.M.; C, 12:47 P.M., during shake on floor above; D, 2:25 P.M.; E, 2:55 P.M., during shake of thirteen minutes.

about 0.3 mg. of zinc per cubic foot, during his working shift, provided he were bag shaking continually. Since, however, bag shaking does not occupy all the operator's time, his exposure to this concentration is by no means continuous.

The actual figures obtained during the settling test, in milligrams of zinc per cubic foot, were as follows: 11:07 A.M. (during shake), 0.29; 11:37 A.M., 0.15; 12:10 P.M., 0.125; 12:47 P.M. (shaking on floor above), 0.263; 1:17 P.M., 0.218; 2:25 P.M., 0.122; 2:55 P.M. (during shake), 0.39. These figures, it must be remembered, represent only a fair average. They will un-

doubtedly vary from day to day, depending on the activity of the plant and on atmospheric conditions.

2. Bag Houses: Oxide Plants A and B

With the exception of the sample taken during the operation of tapping branch rows and headers (job of Subject 4), which showed 1.31 mg. of zinc per cubic foot, all other samples taken from various parts of the bag houses were well under 1 mg. The average figure for the bag shaking operations of oxide plants A and B, excluding the Kadox (trade name for very finely divided oxide made by a special process) block, where the atmosphere is comparatively free from dust, even during shaking—probably because of the fact that this operation is performed on a very small scale as compared with other bag shaking operations—was 0.41 mg. of zinc per cubic foot. This represents the average zinc concentration to which Subjects 9, 10, 11, 12, 13, 14, 15, 18, 19, 20, and 21 are exposed. During a change of collecting bags on the ground floor in oxide plant B, the concentration of zinc in the air during the change reached a higher figure than occurred during the shake—*i.e.*, 0.78 mg. per cubic foot. No figure was obtained for a similar operation in plant A, and the maximum concentration given in Table 2 for plant A bag shakers is, therefore, slightly lower than the high figure for that of plant B men. As each individual is probably not exposed for more than one hour a day to the operation of changing collecting bags, the omission of the figure for this process in plant A is not of consequence.

3. Packing Houses: Oxide Plants A and B

In the packing houses, zinc is fed from a top feeder floor through hoppers to a bolter floor, where the product is cleaned by screening in a rotating drum, and is then passed through closed chutes to packing machines on a packing floor below.

The concentration of zinc in the packing house feeder floors away from the immediate hoppers was 0.136 mg. of zinc per cubic foot (plant B). This figure represents the general conditions on the feeder floor. The concentration around the hoppers varied with the rate at which the bags were emptied. The following figures in milligrams of zinc per cubic foot are samples of the dustiness in both plants A and B during the bag emptying: 0.4, 0.57, 0.89. This last figure represents the maximum zinc concentration to which Subjects 7 and 8 are exposed. Subject 16 is a general clean-up man on the bolter floor of the packing house, plant A. We have unfortunately no figure for the zinc concentration on the bolter floor of this packing house. In plant B, the packing house bolter floor concentration is 0.56 mg. per cubic foot, and we have used this figure as representing the concentration to which Subject 16 is exposed.

Subject 5, who cleans used collecting bags on the bolter floor of plant B packing house, by shaking them against a standard, is exposed for about an hour each day, while he performs this operation, to a higher zinc concentration than that existing on the bolter floor in general. A sample taken during this bag shaking

operation, 8 feet away from the operator, contained 1.25 mg. of zinc per cubic foot. Except for approximately one hour's bag shaking per day, Subject 5 spends his time repairing used bags and is exposed, during this period, to the 0.56 mg. of zinc per cubic foot which exists in the bolter room in general.

Subject 17, a helper on the feeder floor, where Kadox as well as ordinary zinc oxide is packed, is subject to atmospheres varying in concentration from 0.07 to 0.4 mg. of zinc per cubic foot.

4. French Process Zinc Oxide Plant

Bag house conditions during a shake show a somewhat higher concentration of zinc in this plant than in oxide plants A and B, the maximum concentration obtained during a shake being 0.82 mg. of zinc per cubic foot. The sample showing the highest concentration of zinc in this plant was obtained during the mix box operation. This sample was taken in the mix box itself at approximately the nose level of the mix box man (Subject 3). On analysis, it proved to have 1.64 mg. of zinc per cubic foot. The sample taken at the bottom of the reheater in this plant—the atmosphere to which Subject 24 is exposed—showed a concentration in zinc per cubic foot of 0.03 mg.

5. Blue Powder or Zinc Dust Plant

The operation of emptying and recharging the furnaces in this plant is accompanied by an exposure to concentrations of zinc which vary greatly with the operator's distance in feet away from the furnace. The figures range from 2.04 mg. per cubic foot 2 feet away from the furnace, to 0.176 mg. 6 feet away from the furnace. The high temperature of the fume in this operation causes it to rise rapidly beyond the operator's breathing level, so that his exposure to very high concentrations is momentary. As the normal position of the operator is about 4 or 5 feet away from the furnace, the concentration to which he is exposed during the greater part of the operation is not nearly so high as the maximum figure obtained in this room. Subject 2 is employed at this operation.

The dust sample taken during the screening of blue powder gave the highest concentration in zinc of all the samples taken in this investigation, *i.e.*, 3.7 mg. per cubic foot. This sample was taken 5 to 6 feet away from the operator, and represents approximately the atmosphere to which Subject 1 is exposed two to three hours a day. Weather conditions (season, temperature, and amount of wind, especially) probably play an important part in the zinc concentrations in this plant, because of their influence on the rate at which the fume will rise.

6. Lithopone Packing House

In the lithopone packing house there are two floors. The top one is a feeder floor where the lithopone is brought in by a belt conveyor and is dumped mechanically into a receiving bin. From this it is conveyed mechanically by way of a packer bin to the packing floor below, and dropped into the packing machines. In this top room, lithopone is also at times emptied

from bags and shoveled upon the belt conveyor.

Except for a sample taken over the receiving bin (1.12 mg. of zinc per cubic foot), where the operator works only when plugging occurs, all zinc concentrations in the lithopone packing house were low. Sample analyses were as follows: top floor of packing house, beside packer bin, 0.14 mg.; top floor packing house, where bags are emptied, 0.177 mg.; packing room, beside mechanical packer, 0.067 mg. The low concentration of 0.067 mg. represents the atmosphere to which Subjects 22 and 23 are exposed. Subject 6, who works on the top floor, is exposed to a range of zinc concentration of from 0.14 to 1.12 mg.

Table 2 contains the following data grouped together in summary form: ages of subjects, terms of employment, places of work and special jobs, zinc compounds to which individuals are exposed, ranges of zinc concentrations which exist in the particular parts of the plant in which individuals work, and radiographic chest findings. The subjects are arranged in numerical order according to the maximum concentrations of zinc to which they are exposed during any part of their day's work. That is to say, Subject 1 is exposed at some time or other during the course of his employment to the highest zinc concentration of any man in the group. By this method of listing we have attempted to group the men in the order of the extent of their exposure to zinc. This same method of numbering is used throughout the paper, so that Subject 1 of Table 2 is the Subject 1 of all other tables.

It is very interesting to compare the maximum degrees of dustiness to which our workers are exposed with the zinc concentrations which Drinker[2] and his associates have determined experimentally to be threshold ones for obtaining metal fume fever reactions. This investigator, working with freshly generated zinc oxide, very dry and in a very fine state of subdivision, has found that an individual unaccustomed to zinc, breathing slowly and deeply this fine zinc oxide dust in concentrations of approximately 1.6 to 2 mg. per cubic foot for fifteen minutes or more will develop a low grade metal fume fever reaction—that is, discomfort and aching and perhaps a slight rise in temperature. Zinc oxide, it should be pointed out, though very highly dispersed when freshly generated, rapidly aggregates. Metal fume fever reactions are apparently entirely dependent on the number of particles which actually reach the lung alveoli and actually stay there, and this number varies with the degree of dispersion of the particles in question in the air breathed.

The oxides to which workmen in our series are exposed are, in the main, minutes, hours, or days old and are, therefore, highly aggregated. The large particles of the aggregated oxide are filtered out much more readily in the upper respiratory passages than are fine oxide particles and the number reaching the alveoli is consequently much less than when fresh fume is inhaled. A man breathing air containing fresh oxide at one time, and old oxide of the same zinc concentration at another, would inhale into his alveoli very many more dust particles in the first case than in the

[2] Unpublished data. Personal communication.

TABLE 2.—SUMMARY OF DATA ON AGES, TERMS OF EMPLOYMENT, TYPE OF WORK, DEGREES OF EXPOSURE TO ZINC, AND RADIOGRAPHIC CHEST EXAMINATIONS OF TWENTY-FOUR ZINC WORKMEN

No.	Age	Term of Employment		Place of Work	Special Job	Zinc Product	Concentration of Zinc		Radiographic Findings
		By Company	On Special Job				Maximum	Minimum	
	yrs.	*yrs.*	*yrs.*				*mg./cu.ft.*	*mg./cu.ft.*	
1	40	10½	6	Blue powder plant	Part time blowing dust and refuse out of flues under spelter furnaces; 2 to 3 hrs. a day screens zinc dust—partly hand screening, partly machine.	Metallic zinc dust	3.7 (2 to 3 hrs. a day)	Unknown	Moderate fibrosis throughout both lungs. May be an early pneumonokoniosis. Apparent enlargement of the aorta. ? syphilis.
2	41	9½	3	Blue powder plant	Charging retorts; drawing blue powder; firing furnaces and muffle kiln; cleaning fire: removing ashes and wheeling in coal.	Metallic zinc dust	2.04	Under 0.176	Normal lungs.
3	52	10	5	French process oxide plant	Mix box man; mixes different grades oxide in large box and then shovels mixture into elevator.	Oxide	1.64	Under 0.470	Hilus markings pronounced. Moderate diffuse fibrosis, suggestive of chronic bronchitis. Lungs are clear.
4	63	35½	14½	Oxide plant B bag room	Tapping on sheet iron branch rows and headers and sheet iron hoppers in bag room to loosen oxide clinging to inside of branches and hoppers; occasionally shakes out and bundles old filtering bags.	Oxide	1.31 (fairly continuous)	0.122	Smooth diaphragm. Normal heart. Slight increase in hilus shadows—not unusual at this age. Lungs are clear.

					bundles old filtering bags.				
5	45	15	2	Oxide plant B packing house	Cleans bags by shaking—very dusty; repairs collecting bags.	Oxide	1.25 (not more than 1 hr. a day)	0.560	Moderate diffuse fibrosis, possibly suggestive of beginning changes such as occur in pneumonokoniosis.
6	47	9	7⅔	Lithopone plant packing house	Bolter floor feeder; sees that lithopone is carried on conveyors to bolters; cleans up around bolters and hoppers.	Sulphide	1.12	0.140	Normal lungs.
7	51	23	5	Oxide plant B packing house	Feeder floor; removes loaded bags from trucks; places them on feeder hoppers; pours oxide out of bags into hoppers.	Oxide	0.89	0.136	Right chest is slightly cloudy, suggestive of an old pleurisy. Lungs are fairly clear.
8	50	13	12½	Oxide plant B packing house	Feeder floor; removes loaded bags from trucks and places them on feeder hoppers; pours oxide out of bags into hoppers.	Oxide	0.89	0.136	Lungs are clear. Hilus shadows increased, suggesting nonspecific fibrosis such as may follow any nonspecific irritant—*e.g.*, whooping cough, etc.
9	36	15⅓	13½	Oxide plant B bag room	Bag shaker; shakes long filter bags; removes loaded bags; repairs leaks in bags; (replaces ones that have failed, and sweeps up oxide scattered around hoppers.	Oxide	0.78	0.122	Normal lungs.
10	42	10	2	Oxide plant B bag room	Bag shaker, etc.	Oxide	0.78	0.122	Hilus shadows increased. No lung changes.
11	32	7	3	Oxide plant B bag room	Bag shaker, etc.	Oxide	0.78	0.122	Normal lungs.
12	22	3½	1½	Oxide plant B bag room	Bag shaker, etc.	Oxide	0.78	0.122	Slight bronchial scarring about the hilus. Lungs are clear.
13	43	2½	2⅓	Oxide plant B bag room	Bag shaker, etc.	Oxide	0.78	0.122	Normal lungs.

TABLE 2.—*Continued*

No.	Age	Term of Employment		Place of Work	Special Job	Zinc Product	Concentration of Zinc		Radiographic Findings
		By Company	On Special Job				Maximum	Minimum	
	yrs.	*yrs.*	*yrs.*				*mg./cu. ft.*	*mg./cu. ft.*	
14	21	2	2	Oxide plant B bag room	Bag shaker, etc.	Oxide	0.78	0.122	Normal lungs.
15	30	2	1⅓	Oxide plant B bag room	Bag shaker, etc.	Oxide	0.78	0.122	Normal lungs.
16	19	3	3	Oxide plant A packing house	Bolter floor man; sweeps floor and cleans up around bolters.	Oxide	0.56	0.560	Bilateral thickening of bronchial structures toward apices, suggestive of obsolete apical tuberculosis.
17	20	3	1⅔	Oxide plant A packing house	Packing house helper; any helping job.	Oxide	0.40	0.070	Slight increase of shadows at hili and at both apices, suggesting nonspecific fibrosis. Otherwise lungs are clear.
18	49	11½	4	Oxide plant A bag room	Bag shaker, etc.	Oxide	0.34	0.088	Normal lungs.
19	30	4½	4	Oxide plant A bag room	Bag shaker, etc.; also works on sulphide blocks.	Oxide and sulphide	0.34	0.088	Slight fibrosis around trunks leading to apices and sharp discrete areas indicating old lesion, both suggestive of nonspecific fibrosis. Lungs are clear.

20	41	4½	½	Oxide plant A bag room	Bag shaker, etc.	Oxide	0.34	0.088	Normal lungs.
21	53	15½	2	Oxide plant A bag room	Bag shaker, etc.	Oxide	0.34	0.088	Normal lungs.
22	35	12	6	Lithopone plant packing house	Works on a packer; handles empty and loaded barrels and bags, and heads loaded barrels.	Sulphide	0.067	0.067	Slight fibrosis around hili. A few calcareous glands, indicating a childhood tuberculosis. Lungs are clear.
23	45	17½	3	Lithopone plant packing house	Works on a packer; handles empty and loaded barrels and bags, and heads loaded barrels.	Sulphide	0.067	0.067	Normal lungs.
24	43	5½	5½	French process oxide plant	Reheater man; receives into pans and rakes oxide which has gone through reheater.	Oxide	0.030	0.030	Normal lungs.

second. The larger aggregates, stopping in the upper respiratory tract, are, to a considerable extent, coughed up and spit out, blown out with nasal secretions, or swallowed.

Lithopone is heavier than zinc oxide and is also highly aggregated and, therefore, falls into an even lower class than mature oxide from the point of view of the amount reaching the alveoli. Zinc dust is fine but we have, as yet, no comparative data as to its particle size in relation to that of oxide.

Three of the men in our series (Subjects 1, 2, and 3) experience, during their maximum zinc exposures, air concentrations of zinc higher than those which Drinker required to obtain threshold metal fume fever effects with young oxide. One of these men is exposed to old oxide, the other two to metallic zinc. All three of them report never having had chills or "shakes."

V. Possible Routes of Zinc Absorption

There are three possible routes by which zinc may be absorbed by men handling zinc or its compounds industrially—the respiratory tract, the skin, and the digestive tract. Without doubt, the respiratory tract in our subjects is the important portal of entry. Metallic zinc, zinc sulphide, and zinc oxide are all relatively insoluble, and the amounts of zinc actually absorbed as a result of contact of these substances with the skin are probably negligible. The gastro-intestinal tract is, however, a portal of entry which must be taken into consideration. Undoubtedly, the men do swallow some of the dust which they inhale and, especially when eating

during work, some of that which coats their faces and hands.

To evaluate the actual amount of zinc absorbed by a given individual is practically impossible. Assuming the same degree of exposure in several individuals, such variable factors as rates and depth of respiration, amounts of tidal air, areas of absorbing surface, etc., enter in to alter the amounts of the metal which eventually reach the blood stream of a given individual. The only light which we can throw upon the question of the actual amounts of zinc absorbed comes from our data on the amounts of zinc actually excreted by our various subjects—a matter which we will discuss later. We are not prepared to say with assurance whether or not excreted zinc is a measure of the amount of zinc absorbed. It seems probable, however, from animal experiments now being carried on in the Department of Physiology of the Harvard School of Public Health, that zinc, unlike lead, is not stored in the body in significant amounts for long periods but is excreted in amounts approximate to those absorbed.

VI. General Working Conditions

The working conditions under which the subjects of this study are employed are those of any modern metallurgic industry. The men are encouraged to be clean in their personal habits, and usually take a shower followed by a change of clothing after a shift of eight hours. Shower baths, washrooms, and dressing rooms are provided. The men wear, in the dustiest operations, the King respirator with a fair degree of regularity. Its use was omitted for the day preceding the study.

VII. Outline of Clinical and Laboratory Procedures

The subjects for this study were admitted to the hospital in the late afternoon within one or two hours following active work, and remained there for forty-eight hours. All but one man had taken a shower bath before admission. The men cooperated willingly in the investigation. They were paid the usual daily wage during the time spent in the hospital. Their replies to questions were prompt, an interpreter assisting whenever necessary, and were, we believe, unbiased by any considerations as to possible effect on material welfare.

During their stay in the hospital, the men were up and about and were allowed a diet without restriction and tobacco according to their taste. A compound cathartic pill was usually given on the evening of admission to insure adequate evacuation during the unaccustomed inactivity.

A detailed history and a careful physical examination was made of each subject. In addition, the following laboratory procedures were undertaken:

a. A blood sample was secured from each man on the evening of admission for determination of zinc content by the Lutz (31) urobilin method. On the morning of the day of discharge, a second blood specimen was withdrawn for a second zinc determination.

b. The total amount of urine passed by each man during each twenty-four hours of his stay in the hospital was collected. These specimens were ex-

amined chemically for albumin, sugar, and total zinc content (by the turbidimetric method), and microscopically for casts, pus, blood cells, etc.

c. The total fecal output of each man for each twenty-four hours was collected for total zinc determinations by titration with potassium ferrocyanide. Occult blood in the stools was also tested for by the benzidine reaction. The special diet restriction necessary for the rigorous application of this occult blood test was, however, not followed. The stools were passed directly into cardboard containers.

d. White and red blood counts, hemoglobin determinations, and differential blood counts were made on each subject, usually the day following admission. A Wilson modification of the Romanowsky stain was used for the differential count. The hemoglobin standard was checked and corrected with the Newcomer glass standard.

e. A chest radiograph was taken of each man.

VIII. Results of Clinical and Laboratory Examinations

1. Clinical Findings

The three following case reports will serve to illustrate the detail with which the past histories were taken and the character of the physical examinations which were made upon the subjects of this investigation. The three men in question have been in the employ of the Company for periods varying from four and one-half to thirty-five and one-half years and are therefore excellent examples of men long exposed to zinc. Two of the subjects work with zinc oxide—one of these with zinc sulphide as well—and one with metallic zinc. Following these illustrative case reports, we will summarize the results of the clinical findings on all twenty-four of the men.

Illustrative Case Reports

Case 1.—This man, an Hungarian, 40 years old, has been in the employ of the Company at various jobs for ten and a half years, for the last six in the blue powder plant. He now works part of the time with the blow-out gang, blowing dust and refuse out of the flues under the spelter furnaces. Two to three hours a day he screens zinc dust in the blue powder plant, partly by hand and partly by machine. This work of screening blue powder involves exposure to higher concentration of zinc in the air than any other operation in the plant. While screening, this man usually wears a respirator.

Family History.—The subject is married and has six children. His father and mother are dead of unknown causes. One brother is alive.

Past Medical History.—He recalls having had, at the age of 7 or 8, chills and fever associated with a rash—presumably scarlet fever. He has had occasional slight headaches. Otherwise his past medical history is negative. He has had no ear trouble, nosebleed only once, no dyspnea, no cough, no neuromuscular nor genito-urinary trouble. He eats heartily, his bowels move regularly, usually twice a day, and his weight has not varied more than 2 to 3 pounds for a number of years. He was a partaker of beer in days gone by. He has never had "shakes" and does not consider his health in any way impaired in consequence of his work.

Physical Examination.—This subject is a well-built, fairly robust man, weighing 140 pounds, with ruddy face and exceedingly clear skin. There are one or two scars of leech applications over the spine, but no evidence of old furunculosis.

Head examination shows scanty hair over the temples; there is no cranial tenderness. The sclerae are clear; both pupils are equal and react normally to light and

accommodation; convergence is good and there is no nystagmus. The nasal septum is displaced slightly to the left but breathing space is good. The canals and ear drums are clear. The pharynx is slightly injected and some persistent and encrypted tonsillar tissue is present. There are a few snag teeth and a moderate grade of pyorrhea, but the mouth on the whole is in fairly good condition. The tongue is clean and protrudes in the midline. No glands are palpable in the neck. There are a few scars of small old sinuses on the right side of the neck, but these are well healed and freely movable.

Chest examination shows a full chest with both clavicles slightly prominent; respiratory movement is free. Tactile fremitus is transmitted equally on both sides; the percussion note is everywhere clear; resonance is increased within normal limits on deep inspiration; breath sounds all over the chest are normal, being clear and devoid of râles on both inspiration and expiration. The point of maximum impulse of the heart is felt in the fifth interspace, 10 cm. from the midline. The region of cardiac dulness extends 12 cm. to the right in the fifth interspace. Heart sounds are clear at the apex and base; there are no murmurs. Radial pulses are equal, regular, and of moderate volume. Systolic blood pressure is 122 mm. Hg; diastolic, 68.

Examination of the *abdomen* shows good tone of the abdominal muscles. There is no tenderness and no hernia. The liver dulness extends 2 cm. below the costal margin.

The *extremities* show well-developed musculature. Deep reflexes are present, equal and somewhat sluggish.

Laboratory Findings.—Examination of the *urine* shows a specific gravity of 1.010; no albumin; no sugar; no casts, pus cells, nor red cells.

Blood examination shows 82 per cent. hemoglobin; 5,270,000 red blood cells; and 10,000 white blood cells per cubic millimeter of blood. A differential count shows the following percentages of cells; polymorphonuclear leukocytes, 68; small lymphocytes, 17; large lymphocytes, 3; large mononuclears, 4; transitionals, 6; and basophils, 2.

Quantitative analyses of blood, urine, and feces for *zinc* give the following results: blood, 0.431 and 0.5 mg. per 100 c.c., first and second day, respectively; urine, 0.39 mg. and 1.38 mg. per 100 c.c., first and second day, respectively; feces, 27.63 mg. per twenty-four hours (second day).

X-ray plate of the chest shows moderate fibrosis throughout both lungs. This condition may possibly indicate an early pneumonokoniosis. The plate shows an apparent enlargement of the aorta, suggestive of syphilis.

CASE 4.—This man, an American, aged 63 years, has been in the employ of the Company since 1890. For fourteen and a half years he has been employed in the bag room of oxide plant B. His work consists in tapping on the sheet iron branch pipes and headers and the sheet iron hoppers connecting the outside furnaces with the oxide filtering bags, the purpose of this tapping being to loosen the oxide clinging to the inside of the pipes and hoppers. Occasionally he shakes out and bundles old bags. He wears a respirator much of the time as his work is very dusty. He also wears a hood to protect his head and neck from the hot oxide.

Family History.—This subject is married and has six children in good health, three of them working in the plant. His father died at the age of 78. His mother is living, aged 88. He has six brothers and two sisters, all living and well.

Past Medical History.—He remembers nothing of his childhood diseases and recalls no time, beyond an occasional few days, lost from work on account of illness. He recalls having had metal fume chills the first two weeks following employment in the zinc industry in 1890, and only once or twice since then. He reports having had occasional very slight frontal headache up until one or two years ago. He can see well at a distance but requires glasses for reading and writing. He has had no nosebleeds and no disturbances of hearing. His teeth have been neglected and give him considerable trouble. His past history is negative for dyspnea, pleural pain, and edema. He has had no cough except with occasional coryza. He occasionally expectorates material tinged with oxide, but only on extreme coughing. He eats well, his bowels move regularly once or twice a

day, and he has never suffered from abdominal pain. Recently he has gained slightly in weight. He drinks beer moderately. His neuromuscular history is negative as is likewise his genito-urinary past history. He has had no burning on micturition nor nocturia.

Physical Examination.—The subject is a small spare man, 5 feet, 4 inches tall, and weighing 127 pounds. His skin is clear and there is no evidence of any past furunculosis. His hands show no marked callus.

Examination of the *head* shows hair rather scanty over the temples; there is no cranial tenderness. Slight puffiness is evident beneath the lower eyelids. The sclerae of his eyes are somewhat injected, and there is a distinct *arcus senilis* present. Both pupils are equal in size and react normally to light and accommodation. Muscular tests show convergence of the right eye to be slightly weak; there is slight nystagmus on extreme deviation of the bulbs in either direction. Ophthalmoscopic examination shows clear media and elongated nerve heads. There is a bright orange reflex. The nasal septum is slightly displaced to the left, restricting somewhat the breathing space on the left. The drums of both ears are obscured by wax in the canals. Tonsillar tissue is atrophic and the pharynx somewhat injected. Teeth are in very bad condition, numerous snags broken off at the gum level being present. There is marked erosion of the gum and pyorrhea about the few remaining lower teeth. No lymphatic glands in the neck are palpable.

Chest examination shows the right clavicle very slightly prominent. The chest contour and chest movements are symmetrical. Tactile fremitus is transmitted equally on both sides; the percussion note is everywhere strikingly clear; pulmonary resonance is lowered with deep inspiration about 3 cm. on the left side and 2½ cm. on the right. On auscultation, the breath sounds seem slightly distant for a man of this build. A few transient coarse râles can be heard over the larger bronchi on the right side, but no other râles either on inspiration or on expiration. Whispered breath sounds show increased transmission at the apices. Radial pulses are regular in frequency and rate, and the vessel walls are not palpable; there is a slight increase in volume on the left side. The point of maximum impulse of the heart is felt in the fifth interspace, 10 cm. from the midline. The region of cardiac dulness extends 11 cm. to the right in the fifth interspace. Heart sounds are clear at the base and at the apex; there are no murmurs. Systolic blood pressure is 188; diastolic, 97.

Examination reveals a slightly distended *abdomen*. In the upper quadrant of the right rectus there are two small lipomas, measuring approximately 2.4 cm. in diameter, and extending very slightly above the normal contour of the abdomen. There is no tenderness nor muscle spasm. Liver dulness extends about 1 cm. below the costal margin. There is slight bulging at the external rings on coughing.

Examination of the *extremities* shows fairly well-developed musculature. Deep reflexes are present and equal; there is no tremor. Slight fine varicosities are present on the left leg below the knee.

Laboratory Findings.—Examination of the *urine* shows a specific gravity of 1.008; no albumin; no sugar; no casts, pus, nor red cells.

Blood examination shows 82 per cent. hemoglobin; 5,502,000 red blood cells; and 14,400 white blood cells. A differential count shows the following percentages of cells: polymorphonuclear leukocytes, 67; small lymphocytes, 8; large lymphocytes, 10: large mononuclears, 2; transitionals, 13.

Quantitative analyses of blood, urine, and feces for *zinc* show the following results: blood, 0.466 and 0.5 mg. per 100 c.c., first and second day, respectively; urine, 0.37 and 0.19 mg. per 100 c.c., first and second day, respectively; feces, 54.31 mg. per twenty-four hours (second day).

X-ray plate of the chest shows a smooth diaphragm and lungs clear. There is a slight increase in hilus shadows, not unusual at this age. The heart is normal.

CASE 19.—This man, a Portuguese, 30 years old, has been in the employ of the Company for four and a half years, for the last four years as a bag shaker in the bag room of plant A. He also works on the sulphide blocks.

Family History.—The subject is married

and has had two children, both of whom died in infancy. His mother and father, aged 62 and 63, are both living and well. One brother and one sister are living and well.

Past Medical History.—He has no recollection of childhood diseases and denies any illnesses in spite of close questioning. He reports having had no headaches, no sore throats, no nosebleeds, no disturbances of vision or of hearing, no dyspnea, no pleural pain, no cough, no hemorrhages. His appetite is excellent; he eats three large meals a day and any kind of food. His bowels move twice daily; he has no past history of vomiting or of digestive discomfort of any kind. He does not use beer or wine to excess but he smokes ten to fourteen cigarettes a day. His adult weight has remained stationary. His genito-urinary and neuromuscular past histories are negative.

Subject 19 has worked in the bag room for four years; he has never had "shakes" or health difficulties due to his employment of which he is aware.

Physical Examination.—This subject is a rather slight, wiry individual, 5 feet, 6 inches tall, weighing 125 pounds. His skin is everywhere exceptionally clear and soft except for his hands, where there are well-developed calluses over the flexor surfaces of the fingers.

Head examination shows some irregularity in the occipital region. There is no cranial tenderness. Both pupils are rather large, equal, and react to both light and accommodation. Ophthalmoscopic examination shows the media clear, and orange-red fundic reflexes. The nerve heads are clearly outlined and both show some pigmentation. The vessels show a marked tendency to ptosis but are not at all full. The cup is pronounced and rather eccentric. The nares are clear and there is good breathing space. The tonsils are atrophic; the pharynx is clear and the tongue clean. The teeth are in good condition but show some tobacco stain; there is very slight pyorrhea. No lymphatic glands in the neck are palpable.

The *chest* is full formed and symmetrical with movement unrestricted. The right clavicle is slightly prominent. Breath sounds are equally transmitted on both sides. The percussion note is everywhere clear except for the common increase in force at the right apex. The pulmonary resonance descends within normal limits on deep inspiration on both sides. Auscultation reveals normal breath sounds throughout, with a slight expiratory prolongation at the right apex as would be anticipated. There is no roughening of breath sounds, and no râles. The point of maximum impulse of the heart can be seen in the fifth interspace 9 cm. from the midline. The region of cardiac dulness extends 10 cm. in the fifth interspace. The right border is not made out. Heart sounds are clear at the apex and base. In the latter region they seem slightly distant. The radial pulse on the left side shows a slight increase in volume over that on the right. The pulses are regular in force and length; the rate during the examination is somewhat increased over normal. Systolic blood pressure is 114; diastolic, 65.

Examination of the *abdomen* shows well-developed musculature. There is a small nodular thickening with slight subcutaneous injection at the margin of the navel about 3 cm. in diameter. There is no abdominal tenderness and no hernia. The liver dulness extends about 2 cm. below the costal margin.

The musculature of the extremities is well developed. The deep reflexes are sluggish and equal; there is no tremor.

Laboratory Findings.—Examination of the *urine* shows a specific gravity of 1.030; no albumin; no sugar; no casts, pus cells, nor red cells.

Blood examination shows 82 per cent. hemoglobin; 5,470,000 red blood cells; and 14,200 white blood cells. A differential count shows the following percentages of cells: polymorphonuclear leukocytes, 74; small lymphocytes, 10; large lymphocytes, 5; large mononuclears, 2; transitionals, 7; eosinophils, 1; and basophils, 1.

Quantitative analyses of blood, urine, and feces for *zinc* gave the following results: blood, 0.6 and 0.4 mg. per 100 c.c., first and second day, respectively; urine, 1.94 and 1.95 mg. per 100 c.c., first and second day, respectively; feces, 39.45 and 32.96 mg., first and second day, respectively.

X-ray examination of the chest shows

slight fibrosis around the bronchial trunks leading to the apices, and a few sharp discrete areas of fibrosis indicative of an old lesion, both conditions suggestive of a nonspecific fibrosis such as may follow any nonspecific irritant—whooping cough, for example. The lungs are clear.

Summary of Histories and Physical Examinations

The general results of the histories and clinical findings upon all twenty-four of the men may be summed up as follows:

Duration of Employment:

The figures for duration of employment (given in full in Table 2) were taken from the employment office reports and include the periods of time during which the various subjects have been in the Company's employ, and the period of time, also, during which each man has been working on the special job on which he is now engaged. The figures for employment on present jobs are not accurate indices of length of exposure to particular compounds since the majority of men have had similar previous exposures, interrupted, for facility of operation and not because of hygienic considerations, by transfers to other work. In the main, the men have all been exposed to zinc, to a varying extent but in some form or other, during the entire period of their employment by the Company.

It should be borne in mind that the plants at which these men are now working have been in operation for only twenty-one years and that men who have been transferred from similar operations elsewhere to this town have, with one or two exceptions, been advanced to positions above those represented in the present group. Consequently, men employed for over twenty years are, with two exceptions, not found in this series. The labor turnover in the plant is not particularly high. The following is a tabular summary of the lengths of time during which our subjects have been in the employ of the Company and during which, therefore, they have been more or less continuously exposed to zinc.

Duration of Employment	*Number of Men*
yrs.	
35½	1
23	1
17½	1
15–16	3
12–14	2
10–12	4
9–10	2
7	1
4–6	3
3–4	3
2–3	3

Incidence of Metal Chills:

In this plant the problem of metal fume fever (zinc "shakes," brass-founders' ague, etc.) is not an important one. The construction of the oxide furnaces and the ventilation over them is of such a nature that the smelters and furnace men are not subjected to the inhalation of freshly generated zinc oxide fume to an extent sufficient to cause anything more than a rare occurrence of chills. We have, therefore, not included any smelters in our series but have selected men engaged at jobs in which the zinc exposure from dust inhalation is much greater than that to which the smelters are subjected. Definite chills and fever or even malaise and headache among the men continuously exposed to mature zinc oxide dust are uncommon, except perhaps during the

first few days of contact, and are regarded as so unimportant by the men when they do occur that it has been difficult to persuade employees in general to report their existence to the medical adviser in the plant. This is true, in spite of the fact that, in the main, the most trivial accidents and complaints are reported. Isolated instances of chills have come to our attention in men working in ammonium chloride and cadmium. Nine of the twenty-four men in our group reported the occurrence of "shakes" within the first few days after their first exposure to the suspended oxide. Three of these experienced a recurrence of "shakes" once or twice after the first week or two of employment. Only one man in the series was obliged to remain away from work because of the ague. Neither of the two men working with metallic zinc dust has ever had the ague.

Family Histories:

Significant familial illness was not noted. The number of children of the men varied from one to nine. The oldest worker, aged 63, employed for thirty-five and one-half years by the Company, has six children, all healthy and born during his period of employment; three of them work in the plant. Miscarriage was exceptional among the workers' wives.

Past Medical Histories:

The incidence of past febrile diseases was low; typhoid and influenza were noted but their course was not atypical. Pneumonia, following influenza, occurred once among the group. Herniorrhaphy had been necessary in two men. One had had a sarcoma, originating in the buttocks, which had been removed five years previously.

Head.—Seven of the twenty-four men mentioned having occasional headaches, but they were not severe or frequent. *Visual disturbances:* No visual disturbances were reported except in a few cases errors of refraction which necessitated the wearing of glasses. *Hearing:* Occasional temporary impairment of hearing following the accumulation of impacted cerumen and oxide dust was reported. In one man there was permanent deafness following typhoid fever. *Nose:* Occasional epistaxis was mentioned by two men. *Mouth and throat:* Almost all of the men admitted gross neglect of their teeth. Dental hygiene has not been emphasized in the plant until recently. One man had a history of pharyngitis and three of tonsillitis. There was one instance of peritonsillar abscess.

Cardiorespiratory Disturbances.—A history of mild dyspnea on exertion was recorded in four instances. Of these, one man showed on physical examination arterial hypertension and emphysema. Occasional cough was reported by six men, in two of these in association only with acute coryza. Pleural pain, night sweats, and hemoptysis were emphatically denied. In the last eight years, no cases of pulmonary tuberculosis have developed in the departments where these men are employed.

Gastro-Intestinal Disturbances.—In all except one man, appetite was emphasized as excellent. The men reported that they were hearty eaters and included much meat in their diet. Several men eat four meals daily, not including intermediate nourishment.

Two men gave a history of moderate lead colic in the past, one in 1916, one in 1925. In spite of close questioning, abdominal discomfort of any kind, excepting these two past instances of lead colic, was denied by twenty-two of the men. One man reported occasional attacks of mild abdominal discomfort; the other (Subject 15) reported slight, but more or less continuous epigastric discomfort. This latter subject, however, eats three meals a day regularly, has had no loss of weight, and shows no tenderness nor anything unusual upon abdominal examination. Vomiting was denied by all. Defecation in all instances was said to occur at least once daily. Four men reported two movements daily; one, two to three; the rest, one, or one or two. One man had acute constipation during plumbism nine years prior to this examination. At that time he was engaged in an operation where leaded zinc oxide was prepared. In view of McCord's recent association of gastro-enteritis and gastric ulcer with work in zinc, we would like to stress this absence of significant gastro-intestinal disturbances in the past histories of our men.

Weight Changes.—Fourteen men reported no significant changes in weight. In nine men of varying age, the weight was said to be gradually increasing. One man has lost a few pounds in weight since he was employed in 1921.

Genito-Urinary Disturbances.—Of the twenty-four men, only one admitted venereal infection. Among the others a history of frequency, burning on micturition, and allied disturbances was uniformly absent. Two men reported occasional nocturia; one man, urination regularly once or twice during the night. The urine of these three men is normal.

Physical Findings:

Weight and height observations showed three men to be slightly underweight; fifteen men were overweight; the remaining six were well within normal limits.

Head.—In no case did the scalp show significant change nor was there in any instance cranial tenderness. *Eyes:* Slight scleral injection without discomfort was present in the majority of the men. Anisocoria was noted four times. Ophthalmoscopic examination revealed accentuated cupping in three men, overfilling of the veins in three, and arterial thickening in one. Neither nerve atrophy nor retinal hemorrhage was observed. There were the usual normal variations in the color of the fundic reflex and in the pigmentation about the nerve head. Convergence of the right eye was slightly weak and there was slight nystagmus on extreme deviation of the bulbs in either direction in Subject 4, aged 63, but otherwise there was no evidence of muscular eye weakness observed among the group. *Ears:* A number of men showed a moderate deposit of cerumen mixed with small amounts of zinc oxide in the external canal. *Nose:* Septal deviations happened to be the rule and in a few of the subjects the mucous membrane of the turbinates appeared somewhat thickened and dry. *Mouth and throat:* In the majority of the men, oral sepsis of varying extent was present. Superior dentures were fitted in several cases. In several men the pharynx was injected. *Neck:* A varying degree of slight lymphatic gland enlargement

was noted. Thyroid enlargement was absent.

Chest.—Pronounced variations in contour and form of the thorax were not found. Emphysema was observed twice in large-framed men and except in these two cases and in one other man in whom there was some fixation of the ribs, there was no limitation of respiratory movements. Changes in vocal fremitus transmission were very slight. Percussion note pitch deviations of minor character could be found at the apices in less than one-third; in no cases were there pronounced changes in percussion note. It was always possible to elicit the descent of the lower border of pulmonary resonance on deep inspiration. The usual hyperresonance of emphysema was noted in the two men mentioned above. Auscultation revealed the usual variations in the relation of expiration and inspiration and the minor differences of intensity encountered in any group of healthy individuals. Roughening and harshening of breath sounds were noted over the larger bronchi in six instances. One of these six men showed a coarse râle or two at the end of expiration and a slight nonproductive cough. A few transient coarse râles were heard over the larger bronchi in still another subject. Pleural friction sounds were heard in two men over small areas in the lower lobes. There was no pain nor associated limitation of lung movement.

Cardiovascular System.—Examination of the cardiovascular system by palpation revealed no significant changes. A slight increase of cardiac dulness was noted in three men but radiographs on these subjects showed no increase in the heart shadow. No cardiac murmurs nor irregularities of rhythm were detected in the entire series. There was slight thickening of the radial vessels in four men, aged 51, 50, 49, and 41. *Arcus senilis* was noted in one man, aged 63 years, and a beginning *arcus senilis* in another. One man over 50 showed retinal arteriosclerosis. The highest blood pressures observed were a systolic pressure of 188 with a diastolic pressure of 97 in a man of 63, who has spent thirty-five and one-half years in the zinc industry; and a systolic pressure of 172 with a diastolic pressure of 105 in a second man, aged 45, who has been employed by the Company for fifteen years. The remaining blood pressure readings fell within normal limits. The blood pressure findings on all the men are given in Table 3. Varicose veins were noted in four instances.

Abdomen.—No gross abdominal abnormalities were found. Weakness of the inguinal structures was noted in three men, scars of hernia repair in two. A small ventral hernia was present in one man and a lipoma of the abdominal wall in another. No marked variations in the area of liver dulness were made out. Except for slight tenderness in the hypochondrium in one man, there was no localized nor generalized tenderness. In two individuals of somewhat sensitive and nervous make-up, there was some abdominal muscle spasm.

Extremities and Spine.—Except for a few miscellaneous scars and evidences of healed fractures, no abnormalities were noted. The deep reflexes were always obtained and were recorded as sluggish in nine men

and hyperactive in five. A coarse tremor was noted in one man, who nine years previous had been transferred from a leaded oxide operation because of plumbism.

TABLE 3.—BLOOD PRESSURE AND URINE FINDINGS IN TWENTY-FOUR ZINC WORKMEN

Subject No.	Age	Blood Pressure		Urine Findings[1]			
		Systolic	Diastolic	Sp. Gr.	Albumin	Sediment	
						Casts	White Blood Cells
	yrs.	*mm. Hg*	*mm. Hg*				
1	40	122	68	1.010	—	—	—
2	41	114	60	1.018	—	—	—
3	52	142	70	1.011	—	—	—
4	63	188	97	1.008	—	—	—
5	45	172	105	.....	—	—	—
6	47	136	80	1.018	—	—	—
7	51	128	75	1.035	—	—	—
8	50	130	90	1.013	—	—	—
9	36	108	67	1.018	—	—	—
10	42	134	88	1.020	—	—	—
11	32	136	85	1.016	—	—	—
12	22	128	68	1.008	—	—	—
13	43	125	67	1.017	—	—	—
14	21	108	55	1.010	faint trace	—	—
15	30	122	75	1.012	—	—	—
16	19	138	65	1.008	—	—	a few
17	20	109	60	1.012	—	—	—
18	49	132	75	1.010	+	+	+
19	30	114	65	1.030	—	—	—
20	41	116	67	1.035	trace	occasional	occasional
21	53	118	78	1.020	—	—	—
22	35	128	80	1.016	—	—	—
23	45	114	68	1.008	—	—	—
24	43	128	75	1.014	—	—	—

[1] Sugar and red blood cells uniformly absent.

Skin.—Reports in the literature of irritation of the skin by zinc oxide are very rare. Helpup (24) cited van der Weyde (1865) as finding that the wearing of paper collars which were colored with zinc oxide brought about a cutaneous eruption on the neck, apparently through the formation of an irritating compound of the zinc with the acids of the sweat.

The only other account of skin irritation by zinc oxide of which we are aware is a paper by Turner (32), in which the author reported a dermatokoniosis occurring among zinc oxide workers, especially in the summer, and due primarily to a plugging of the sebaceous glands with zinc oxide, and secondarily to infection. The lesions consisted in a papular pustular eruption which appeared in the pubic

region, on the scrotum and inner surface of the thigh, and, occasionally, in the axilla and on the inner surfaces of the arms. The probable mechanism of the occurrence of this condition is, according to Turner, as follows:

"The bodies and clothing of the men exposed are continuously covered with the oxide dust during the work period. Thus, wherever two surfaces of the body rub together, the oxide powder, the body débris, and bacteria normally present on the skin are rubbed into the glands. This action is greatly facilitated by free perspiration. The plugging of these skin glands produces an ideal incubator for the bacteria" and subsequent infection. The condition occurs, according to Turner, "most frequently during the summer months, and to a lesser degree during the winter months. The consensus of opinion among the workmen is that the occurrence of the disease depends entirely upon personal cleanliness, and that if they take daily baths no trouble is experienced."

Because of this paper by Turner, we were especially interested in observing closely the appearance of the skin of the twenty-four zinc workers in our series. In general, the skin of the men was strikingly clear. Slight acne occurred in three. Careful scrutiny of the axillae and thighs revealed in one man only the scars of pustules, regarded by Turner as of such frequent occurrence among workers exposed to zinc oxide dust.

2. Laboratory Findings

The results of the laboratory findings on our twenty-four zinc workmen are given in full in Tables 2, 3, 4, 5, and 7. The data in these tables may be summarized as follows:

X-Ray Examinations

Twelve of the twenty-four workmen showed lungs normal in every respect. In eight men there was increase in hilus shadows, slight in seven, rather pronounced in one. The lungs were clear in all eight of these cases. This increase in hilus shadows suggests a nonspecific fibrosis about the bronchial trunks, a condition which may follow any nonspecific irritant, such as whooping cough, etc. It has no special pathologic significance, and occurred in our series in about the proportion one would expect to find in men working in an atmosphere containing dust. In the opinion of the X-ray expert to whom we submitted our plates for an independent judgment in regard to them, the amount of fibrosis in our men is just about the amount one would find in any group of men working in an atmosphere containing dust above the usual—street laborers, for example. One man showed a slightly cloudy right chest, suggestive of an old pleurisy. His lungs, however, were clear. Another man, Subject 16, showed bilateral thickening of the bronchial structures toward the apices, suggestive of an obsolete apical tuberculosis.

In two of the men only were there any significant radiographic findings. One of these, Subject 1, showed an apparent enlargement of the aorta, suggestive of syphilis, and a moderate fibrosis throughout both lungs, such as occurs in the early stages of pneumonokoniosis. This man screens metallic zinc and is exposed for three to

four hours a day to the highest dust concentrations determined in our study anywhere in the plant. Subject 5 shows a moderate diffuse fibrosis, possibly suggestive of beginning changes of the type which occurs in early pneumonokoniosis.

Table 2 summarizes the ages, terms of employment, type of work, and degrees of dust exposure of all the men and gives in full the radiographic chest findings. It is interesting to note that Subject 4, a man 63 years old, who has been exposed for thirty-five and one-half years to zinc oxide dust, shows nothing more than a slight increase in hilus shadows, not unusual at his age. His lungs are entirely clear.

Urine

Table 3 gives in full the results of the urine findings in our subjects. Albuminuria with casts was found in two bag room workers, aged respectively 49 and 41. In one of these the amount of albumin was not more than a trace and the casts only occasional. A few white cells were noted in one other man, and a faint trace of albumin in another. Sugar was uniformly absent. The incidence of albuminuria in our series is about the percentage incidence that one would expect in any group of men of the number and age of ours. Fifteen of our subjects, it should be remembered, are 40 or over and all except four are 30 or over. It is interesting and significant to note that the two men showing albuminuria and casts are low down in the list so far as exposure to concentrated zinc dust is concerned, and that the men who are exposed to the highest concentrations of zinc containing dust are entirely free of any clinical or laboratory evidence of kidney damage. Subject 4, who has been extensively exposed for thirty-five and one-half years to zinc, is an instance particularly in point.

We stress this matter because of recent work by Mallory (33) in which he reports obtaining an intracapillary glomerulonephritis from the subcutaneous injection of metallic zinc in fine powder form. "The chief source of danger to man of poisoning with zinc," writes Mallory, "is from inhalation of fumes and dust in occupations involving this metal." Subjects 1 and 2 in our series are men exposed to the inhalation of metallic zinc in fine powder form in high concentration relative to zinc exposure in general in the plant. These men have been exposed in this way for years and yet neither of them shows the slightest evidence of kidney damage. We shall show later, moreover, by our figures on zinc excretion that all our subjects are regularly excreting zinc through the kidneys in quantities much greater than normal. We question whether Mallory's findings have any practical bearing on the evaluation of zinc as an industrial hazard because of the extremely large doses (0.5 to 1 gm.) of zinc powder which this investigator administered, and by a route of absorption to which men are never exposed; because of the relatively low incidence of the occurrence of nephritis in his series (four rabbits out of eleven); because of the apparent connection between the development of the nephritis and the intensity of the local reaction at the site of injection, with the possibility that this local reaction may have been a factor in causing the nephritis; and because of

the fact that the same type of kidney irritation followed the subcutaneous injection of metallic nickel. These are all matters which should be explored further, especially in view of our own findings, before one concludes that the excretion of zinc causes kidney damage.

Feces

Examination of feces revealed no gross abnormalities, such as excess of fat or undigested particles. Without rigorous preliminary preparation of the subjects having been instituted, the benzidine reaction for occult blood was faintly positive in fecal specimens from three men (Subjects 9, 19, and 20) in generally good health. This finding when unaccompanied by any other noteworthy symptom has little significance.

Blood

Hemoglobin readings were first made with the Tallqvist scale and then checked by means of the Newcomer glass standard. The hemoglobin determinations ranged between 72 and 97, the average being 81. *Red blood cells* ranged in number between 4,170,000 and 6,290,000, the average count being 5,396,000. All these figures are within normal limits. The *white blood cells* ranged between 7,400 and 14,400 per cubic millimeter, the average in round numbers being 10,700. Assuming the normal white count to vary between 6,000 and 10,000 cells per cubic millimeter (34, p. 540), we find that fourteen of our twenty-four men showed a slight leukocytosis, an increase due in six cases to an increased number of polymorphonuclear leukocytes (assuming the normal percentage of these cells to be 60 to 72). This tendency to a slight leukocytosis may possibly be interpreted as an expression of a bodily defense mechanism against absorbed particulate matter. The *differential counts* showed nothing significant. They were all essentially within the normal variations as tabulated by Miller (35) from the results of 650 differential counts made on 230 normal individuals. Punctate basophilia was recorded in two men, one of whom had been previously employed in leaded operations. Table 4 gives the results of the blood findings in full.

In view of the emphasis placed upon anemia as one of the symptoms of so-called chronic zinc poisoning, we should like to stress the essentially normal blood pictures in our subjects.

Estimations of the amounts of *zinc in the blood* of our zinc workers showed, in general, a slight increase over the amounts found in control individuals. Table 5 gives in full the zinc content in milligrams per 100 c.c. of two specimens of the blood of each of our twenty-four workmen and of blood obtained from ten control persons. The figures for the controls range between 0.32 and 0.46 mg. per 100 c.c., the average being 0.387 mg.; while the bloods of the zinc subjects range between 0.31 and 0.6 mg., the average being 0.458 mg. This represents an average increase in zinc over the normal of 0.071 mg. per 100 c.c. of blood. This finding is in accord with figures obtained by K. R. Drinker[3] and P. K. Thompson on the bloods of control animals and of animals ingest-

[3] Unpublished data.

ing zinc oxide or inhaling zinc oxide dust. The blood of the zincked animals in general contains a slightly greater amount of zinc than normal. These observations confirm the general opinion that zinc, once it is absorbed, is transported by the blood stream. It seems highly probable from our figures that the blood stream of an individual exposed to the inhalation of zinc is never deluged with the metal, but that small amounts of zinc are being continuously conveyed by it to the organs of excretion.

TABLE 4.—BLOOD FINDINGS IN TWENTY-FOUR ZINC WORKMEN

Subject No.	Hb	Red Blood Cells	White Blood Cells	Polymorphonuclear Leukocytes	Small Lymphocytes	Large Lymphocytes	Large Mononuclears	Transitionals	Eosinophils	Basophils
	%	*per c.mm.*	*per c.mm.*	%	%	%	%	%	%	%
1	82	5,270,000	10,000	68	17	3	4	6	0	2
2	97	4,170,000	7,600	65	15	3	2	11	4	0
3	72	5,690,000	10,600	69	18	1	2	7	3	0
4	82	5,502,000	14,400	67	8	10	2	13	0	0
5	82	5,584,000	10,000	82	5	2	3	6	2	0
6	82	5,270,000	10,400	66	22	2	2	5	3	0
7	87	5,152,000	11,200	60	28	4	1	7	0	0
8	92	6,110,000	11,200	82	4	4	2	8	0	0
9	87	5,460,000	7,500	58	32	0	3	4	3	0
10	82	5,210,000	14,200	54	7	18	4	14	3	0
11	72	5,970,000	13,200	70	11	4	7	5	3	0
12	77	4,920,000	9,600	72	12	5	3	6	2	0
13	87	4,810,000	9,000	65	22	3	5	2	3	0
14	72	5,260,000	8,300	66	23	4	4	2	0	1
15	77	4,310,000	8,000	74	14	3	3	6	0	0
16	72	6,021,000[1]	10,900	82	12	1	0	4	1	0
17	72	6,016,000[1]	11,300	85	5	2	2	6	0	0
18	72	5,490,000	11,400	76	8	5	2	5	4	0
19	82	5,470,000	14,200	74	10	5	2	7	1	1
20	92	5,710,000	9,000	83	9	3	1	3	1	0
21	82	5,430,000	12,400	71	19	4	3	3	0	0
22	82	5,831,000	11,400	69	17	3	2	5	1	0
23	82	4,550,000	13,000	79	11	2	0	6	1	1
24	77	6,290,000	7,400	75	19	1	1	2	1	1
Av.	81	5,396,000	10,700	..	..	..	..	..	..	..

[1] Red cells show punctate basophilia.

Zinc Excretion

The consensus of opinion (Schlossberger (36), Michaelis (37), Mazkewitz (quoted by Sacher), Sacher (12), Lehmann (20)) in regard to the excre-

TABLE 5.—ZINC CONTENT OF BLOOD OF CONTROL SUBJECTS AND OF TWENTY-FOUR ZINC WORKMEN

Subject No.	Zinc Content of Blood per 100 C.C.	
	Controls	Zinc Workmen
	mg.	*mg.*
1	0.32 0.37 0.41	0.431 0.500 .....
2	0.46	0.450 0.550
3	0.43	0.400 0.500
4	0.32	0.466 0.500
5	0.38	0.500 0.400
6	0.37	0.500 0.600
7	0.41	0.400 0.500
8	0.41	0.333 0.454
9	0.36	0.400 0.583
10	0.40	0.437 0.500
11	....	0.412 0.583
12	....	0.375 0.384
13	....	0.466 0.450
14	....	0.384 0.500
15	....	0.500 0.400
16	....	0.375 0.400
17	....	0.533 0.500
18	....	0.500 0.583
19	....	0.600 0.400
20	....	0.450 0.400
21	....	0.437 0.450
22	....	0.310 0.454
23	....	0.400 0.450
24	....	0.466 0.400
Average...	0.387	0.458

tion of zinc is that absorbed zinc is taken up by the blood and temporarily stored by the liver, is excreted in small amounts by the liver into the bile, but, in the main, is gradually liberated by the liver to the blood stream, and is then excreted, to a certain extent into the urine by the kidneys, but chiefly into the feces by the gastro-intestinal tract. If the absorbed zinc is greater in amount than the excretory mecha-

nism can handle at once, zinc is temporarily stored, chiefly in the liver, possibly in other organs, and is liberated as fast as it can conveniently be excreted. Some authors (Lewald, quoted by Sacher (12)) suppose zinc to be excreted in very small quantities in milk, and possibly in traces in cutaneous excretions; but, even if actual ones, these routes of excretion are probably of small importance.

The figures on zinc excretion in our men are extremely interesting, showing as they do that relatively large amounts of zinc may pass for years through the kidneys and the gastro-intestinal tract without producing any damage which can be detected clinically. The normal daily zinc excretion (see Table 6, the data of which were obtained from control subjects living in Palmerton) varies in a healthy individual on an ordinary mixed diet between 0.75 and 1.75 mg. of zinc per twenty-four hours (averaging approximately 0.08 mg. per 100 c.c.) in urine, and ordinarily between approximately 3 and 20 mg. per twenty-four hours in feces. The zinc content of feces may increase greatly, however, if foods especially rich in zinc chance to be consumed. Fairhall,[4] for example, found an increase of from 12 to 70 mg. of zinc in feces during the twenty-four hours following the eating of eight large oysters. The recognition of the universal presence of zinc in foods (Lutz (1)) and of zinc as a normal urinary and fecal constituent (Rost and Weitzel (3), Fairhall,[4] etc.) is extremely important before one attempts to consider the problem of zinc excretion in men exposed to abnormal amounts of it.

TABLE 6.—DAILY ZINC EXCRETION OF NORMAL SUBJECTS OF BOTH SEXES ON AN ORDINARY MIXED DIET

Subject No.	Urine			Feces
	24 Hr. Quantity	Zinc per 24 Hrs.	Zinc per 100 C.C.	Zinc per 24 Hrs.
	c.c.	*mg.*	*mg.*	*mg.*
1	1,570	1.25	0.080	19.50
	1,350	1.25	0.093	18.81
2[1]	1,300	1.00	0.077	2.67
	1,105	0.75	0.068	9.31
3	1,470	1.25	0.085	3.66
	1,270	1.25	0.098	5.54
4	2,170	0.75	0.035	4.75
	1,830	1.00	0.055	3.37
5	980	0.75	0.077	3.28
	1,010	0.75	0.074	3.76
6	1,040	0.75	0.072	10.20
7	1,100	1.00	0.091	17.62
8	1,680	1.50	0.089	14.95
9	1,295	1.25	0.097	5.35
10	1,380	1.75	0.127	15.40
11[1]	1,820	1.75	0.096	13.96
12[1]	2,600	1.50	0.058	14.36
13[1]	2,430	1.00	0.041	14.46
14	1,210	0.75	0.062	4.85
15	1,300	1.00	0.077	14.95
16	1,170	1.25	0.107	4.06
17	1,210	1.00	0.083	5.15
18	1,430	1.25	0.087	4.36
Average	.....	1.12	0.080	9.32

[1]Male.

The amounts of *urinary zinc* in our workmen ranged between 0.12 and 3.93 mg. per 100 c.c., the average being 1.06 mg. Unfortunately, the collection of complete twenty-four-hour specimens of urine was not in all cases rigidly carried out, so that we have expressed our data in terms of milligrams per 100 c.c. rather than in

[4] Unpublished data. Personal communication.

TABLE 7.—DAILY ZINC EXCRETION OF TWENTY-FOUR ZINC WORKMEN ON AN ORDINARY MIXED DIET

Subject No.	Urine	Feces
	Zinc per 100 C.C.	Zinc per 24 Hrs.
	mg.	*mg.*
1	0.39	.....[1]
	1.38	27.63
2	0.94	103.76
	0.85	24.05
3	1.31	130.78
	....	98.76
4	0.37	.....
	0.19	54.31
5	....	55.65
	0.85	19.59
6	0.41	37.90
	1.33	10.94
7	2.22	74.58
	3.06	52.96
8	....	80.08
	0.41	37.69
9	0.13	28.24[2]
	1.70	111.05
10	1.21	14.32
	1.18	21.55
11	1.38	62.15
	1.02	17.16
12	0.89	83.09
	0.51	25.13
13	1.49	36.21
	1.39	21.35
14	3.05	62.96
	0.76	50.53
15	1.42	52.69
	0.69	38.91
16	0.56	101.05
	0.19	33.23
17	0.62	132.67
	0.56	24.99
18	0.62	17.83
	0.50	67.01
19	1.94	39.45
	1.95	32.96
20	0.66	15.54[2]
	0.91	.....
21	0.12	48.23
	0.79	10.13
22	0.29	15.40
	0.33	8.24
23	1.74	53.77
	3.93	33.91
24	0.50	11.48
	....	24.72
Average...	1.06	46.77

[1] Blank indicates that analysis was lost.
[2] Occult blood present.

milligrams of zinc per twenty-four hours. The amounts excreted by a given individual were in many cases approximately equal during each of the two days in the hospital. In other instances, one day's excretion was markedly greater than the other. Subject 7 is particularly noteworthy, showing as he did a zinc excretion of 2.22 mg. per 100 c.c. on the first day, and 3.06 mg. per 100 c.c. on the second. Contrast this large amount of zinc with the normal average of approxi-

mately 0.08 mg. per 100 c.c. And yet this man has been in the employ of the New Jersey Zinc Company for twenty-three years and shows no clinical evidence of kidney damage. Subject 23 also shows a relatively high urinary zinc though he works at one of the least dusty jobs. In general there is no correlation at all between the dustiness of the job and the amount of zinc excreted in the urine.

The figures for *fecal zinc* in our men range between 8.24 and 132.67 mg. of zinc per twenty-four hours. Undoubtedly, a considerable portion of this zinc was swallowed and passed through the gastro-intestinal tract unabsorbed. The compound cathartic pills given to the men on admission doubtless hastened the passage of swallowed zinc through the gastro-intestinal tract, and were probably the occasion in a number of cases, at least in part, of the great discrepancy between fecal zinc the first day and fecal zinc the second day. Table 7 gives in full the figures on the urinary and fecal zinc excretion of our twenty-four subjects.

It is impossible to estimate from our figures what fraction of the fecal zinc represents zinc which has been absorbed into the body and excreted into the gastro-intestinal tract, and what fraction represents swallowed zinc which has passed through the gastro-intestinal tract unchanged. But a determination of these facts is probably not significant; the important point to be brought out is the fact that zinc can pass in considerable quantities continually and for years along the gastro-intestinal tract and actually through its walls, without causing any damage which can be detected clinically. In view of McCord's (29) recent paper in which he associates severe gastro-intestinal lesions in galvanizers with zinc as a probable causative agent, we wish to stress this point of the large amount of zinc in the feces of our men and at the same time the absence of significant gastro-intestinal symptoms.

IX. Summary and Conclusions

Careful and detailed clinical and laboratory studies on twenty-four workmen exposed over periods of time varying from two to thirty-five and one-half years, to the inhalation of varying concentrations of zinc in the form of zinc oxide, zinc sulphide, or fine metallic zinc dust (manufactured, in the main, from ores conspicuously low in lead and low in cadmium) have revealed no acute nor chronic illnesses ascribable to zinc. The workmen, chosen to represent varying types and degrees of exposure to zinc, proved on the whole a vigorous, healthy lot of men, giving no histories of significant past illnesses and showing only such general physical conditions as one would expect to find in any similar group of men of the same ages, of the same social status, and doing approximately the same amount of physical work in an atmosphere with a moderate amount of dust, but with no exposure to zinc. This fact is especially significant, indicating, as it does, that ill health ascribed to zinc, particularly the so-called chronic zinc poisoning often referred to in the literature, is in all probability due to toxic impurities, such as lead, cadmium, arsenic, and antimony, which commonly contaminate zinc ores, and not to zinc itself.

Our study demonstrates that zinc workers absorb and excrete zinc in amounts considerably over the normal, and that they maintain constantly a blood zinc content slightly higher than normal. It is apparent, however, from our investigation that abnormal amounts of zinc may enter and leave the body for years without causing symptoms or evidence, which can be detected clinically or by laboratory examinations, significant of gastro-intestinal, kidney, or other damage. The fact should be stressed that the amounts of zinc in the urine and the feces of zinc workers represent increased amounts of a normal urinary constituent, and not the presence of a metal abnormal to living cells and to metabolic processes.

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HEALTH CONTROL IN MERCANTILE LIFE. A PROBLEM OF CONSERVING HUMAN ENERGY. By *Arthur Brewster Emmons*, 2d, A.B., M.D., Director, Harvard Mercantile Health Work, Boston. Instructor, Practice of Industrial Hygiene, Harvard School of Public Health. Cloth. Pp. 234 with index. New York and London: Harper & Brothers, Publishers, 1926.

This new book describes the work done by Emmons as Director of the Harvard Mercantile Health Work. Six years ago this bureau was organized by a group of public-spirited merchants who, recognizing the value of hygiene and medicine to factories, desired to have these principles put into practice in their stores. Twenty-five stores eventually subscribed to this plan, most of them located in Boston.

Emmons believes implicitly in the value of all current measures of social betterment. At the same time he has not allowed his book to give the impression that such measures, once instituted in stores, always work out satisfactorily or that the task of demonstrating their worth has been or is an easy one.

Emmons' experience is a unique one and for this reason his book may also be considered unique among the numerous books on industrial hygiene and medicine and cognate subjects. No other physician in this country or abroad has had the opportunity to work with and to observe health practices in so many stores. This fact, therefore, commends this volume to all physicians now in the work or anticipating entering such work. Public health workers will also be amply repaid by reading it.

The book may be well considered a manual of practice in mercantile health work that is authoritative and unique.—*Henry B. Elkind.*

DIE SCHÄDIGUNGEN DER HAUT DURCH BERUF UND GEWERBLICHE ARBEIT. Edited by *Karl Ullmann*, *Moriz Oppenheim*, and *J. H. Rille*. Paper. Volume II, Parts 5 to 8, pp. 193–384 with illustrations, and colored plates. Leipzig: Leopold Voss, 1926.

Parts 5 to 8 of Volume II are in some ways the most interesting sections of the book.[1] They take up the important subject of bakers' and confectioners' itch, and also the skin lesions of workers in paraffin, tar, pitch, and soot, as well as several subjects of somewhat less importance, such as the coal tar dyes, turpentine and its substitutes, etc.

Fasal opens with alcohols, ethers, and ethereal oils; Galewsky follows with formaldehyde. There is not much that is new in these sections, but it is interesting to see how small a percentage of the last named may cause trouble. Thirteen cases of eczema were caused by a paste containing only 0.5 per cent. of formaldehyde.

Glaser writes of the lesions in handlers of carbohydrates, especially bakers and makers of sweets and preserves, a field which seems to be more controversial now than formerly when

[1] For review of previous sections see THIS JOUR., 1925, vol. 7, p. 43; 1926, vol. 8, p. 288.

we assumed that meal and sugar were directly irritating and productive of itching eruptions. Recent English studies reject this simple explanation but leave still unsolved the question whether bakers' and confectioners' itch is to be attributed to parasites or to chemicals (common salt, bleaching agents, etc.), or simply to a personal susceptibility to the irritation of damp dough, or to the itching and consequent scratching caused by drying dough and sweat. In modern, mechanical bakeries there is no itch.

Fruit acids, sudden changes from hot to cold solutions, the use of chemicals like quicklime, have their effect. Prosser White believes there is a great difference between the effects of crude and refined sugars. Other lesions come from spurts of boiling syrup, and subsequent infection of the burn. A suppuration around the finger nails in confectioners has long been known as *mal des confiseurs*. Kingery and Thienes traced lesions in jam makers to a yeast-like body which they isolated and grew. Millers' itch has been traced to parasites in the United States, France, Russia, and Germany, as has also the itch of packers using straw, and that of unloaders of wheat. In California rice fields an erythema with suppurative folliculitis has been observed and has been attributed to the silicic acid in the husks of the grains, for those who handle only the polished rice do not suffer from it.

Ullmann's chapter on crude oil, paraffin, and the hydrocarbon group of coal tar compounds is one of great value, for some of the most interesting work on cancer during the last few years has been carried on in this field. Crude petroleum differs in its aromatic hydrocarbon content according to its origin, that from Galicia and Borneo containing the most, the others being relatively free; but the lesions caused by crude petroleum alone are similar to those caused by coal tar, showing that analogous compounds must be present in both. The fractions which are most productive of skin lesions are those obtained in the final processes of distillation, especially the so-called paraffin oil, which is removed by hydraulic pressure from solid paraffin. Probably the terpenes, creosote, phenols, etc., which are found also in these later stages, play their part in the production of "paraffin dermatoses" which are situated not only on exposed parts but wherever oil soaked clothing presses against the skin.

Clinical studies show that some of these oils contain carcinogenic substances, especially those recovered at 200° to 350°C., but also higher fractions, up to 450°C. So far, however, it is impossible to say whether all dermatosis producing compounds are carcinogenic. There are well-illustrated descriptions of the similarities between tar lesions, as seen in workers in brown coal and in anthracite, and paraffin lesions. The differences between the two classes are more quantitative than qualitative, hyperkeratoses being more characteristic of the paraffin, pigmentation of the coal tar. This last is due to photodynamic elements in coal tar, such as anthracene, anthraquinone, and acridine, and, according to Leymann and Koelsch, American pitch is free from photodynamic elements. An interesting evidence of the hematogenic action of some of these compounds was seen during the war when "war melanoses"

were described by Riehl and by Blaschko—symmetrical pigmentation with follicular keratoses, distributed like the lesions of pellagra and resembling those caused by tar but in these cases produced by way of the blood stream and not by external irritation, for, according to these authors, their cause was the adulteration of food fats by mineral oils.

Ullmann reviews the controversy over the Belgian theory which attributes the lesions of briquette makers to the arsenic in the coal dust and treats it with more respect than most German and English writers in this field, but brings forward the experiments of Fibiger who produced the same lesions in animals with arsenic free tar. The illustrations of the pathologic anatomy of paraffin and tar epithelioma are numerous and clear and there is an enormous bibliography including English and American references.

Koelsch writes the chapter on coal tar derivatives, especially dyes, a subject on which there is much literature but a good deal of confusion. It is important to remember that the earlier articles deal with colors which were made by the use of arsenious acid as an oxidizing agent, a method no longer used. Most dyes are harmless; the basic ones, which have a special affinity for cell nuclei, are said to be more harmful than acid or neutral dyes. Blaschko says that there may be an acute erythematous inflammation from the penetration of the poison to the deeper layers, the blood vessels, or an ordinary eczema, depending on the toxic nature, the individual susceptibility, and the occurrence of secondary infection. Scarlet red (amidoazotoluene), brilliant red, acid green, and acid yellow have been used experimentally to produce verrucose and epitheliomatous proliferation, but in industry there are very few cases of skin lesions from these dyes.

As for crude oils, there are several which produce skin lesions, benzene probably only by its fat dissolving property, but others, such as naphthalene, phenanthrene, and anthracene with its derivative anthraquinone, are irritating. Among the intermediates, the nitro derivatives (picric acid, trinitrotoluene, etc.) are important, as are also the chlornaphthalenes ("Perna"), hydronaphthalenes ("tetralin" and "decalin"), naphthylamines, nitrophenols, and aminophenols ("metol"). The work of Hanzlik on aromatic diamines used as fur and hair dyes is quoted.

Glaser discusses turpentine, varnishes, lacquers, and also turpentine substitutes such as tetralin, pyridine (in furniture polish), and the synthetic resins produced from formalin, carbolic acid, and ammonia or caustic soda (bakelite?).—*Alice Hamilton.*